

Corrosion

Official Publication

NATIONAL ASSOCIATION OF CORROSION ENGINEERS



OCTOBER, 1958

No. 10

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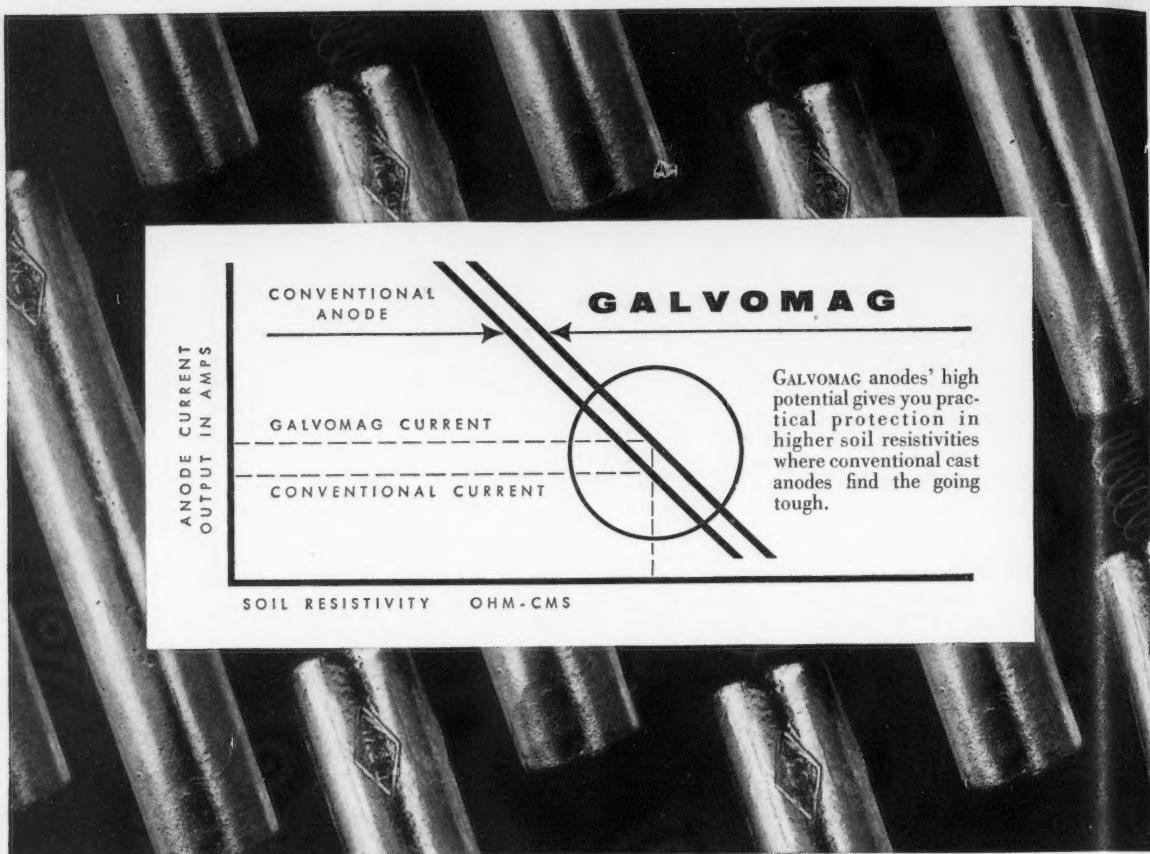
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THIS MONTH'S COVER—This view of the Second National Bank Building under construction in Houston shows the aluminum curtain walls in process of installation. This multiple story building is one of two recently built in Houston with extensive use of aluminum exterior walls. Like other skyscrapers in the city it is fully air-conditioned.



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research and control

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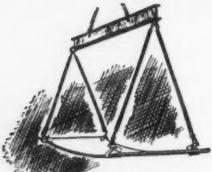
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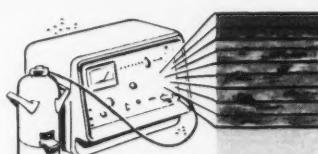
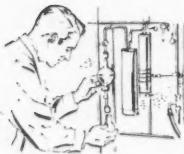
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Now! For the first time, actually look *under* the surface of the coating! See Rust-Oleum *penetrate rust* to bare metal through the "eyes" of radioactivity!

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Nearly three years of research, utilizing radioactive tracing with C¹⁴ radioisotope, enables you to follow Rust-Oleum penetration through the heretofore "unseen" rust area to bare metal. While Rust-Oleum users, for over thirty years, have known that Rust-Oleum penetrates rust to bare metal when applied over rusted surfaces—Rust-Oleum wanted to go even further in bringing irrefutable evidence of this penetration to you.

The methods and results, on which the technical information on these pages is largely based, are presented in a complete thirty page report entitled, "The Development of a Method to Determine The Degree of Penetration of a Rust-Oleum Fish-Oil-Based Coating Into Rust Coatings on Steel Specimens," prepared by Battelle Memorial Institute technologists. Request your copy on your business letterhead without cost or obligation.



1 To trace Rust-Oleum penetration through rust, the Rust-Oleum fish oil vehicle was made radioactive with C¹⁴ radioisotope. The radioactive Rust-Oleum fish oil vehicle was then formulated into Rust-Oleum 769 Damp-Proof Red Primer without changing Rust-Oleum's exclusive formulation or performance of product.

2 Rusted metal test panels were scraped and wirebrushed to remove rust scale and loose rust, according to Rust-Oleum's standard directions for application. The radioactive Rust-Oleum 769 Damp-Proof Red Primer was then brushed on directly over the remaining rust on these rusted test panels and allowed to dry.

3 Then—the surfaces of the rusted panels were shaved at approximate half-mil levels and Geiger Counter readings of Rust-Oleum penetration (radioactivity) were taken at each level down to bare metal. These measurements are shown as "Percentage of Surface Radioactivity" figures on the graph on the opposite page.

Dry film thickness of a coating is important, but, what goes on UNDER the film surface is vitally important, too, in the stopping of rust. Rust-Oleum Stops Rust, because it penetrates the rust to bare metal. The Rust-Oleum fish oil vehicle works around the rust particles and through the fissures and crevices in the rust formation to the bare metal. It doesn't "bridge-over" the tiny, microscopic pits in the metal—BUT, actually goes into these pits to drive out air and moisture and coat the metal with a penetrating, low-surface-tension film that expands and contracts with the metal. Because of this unusual penetration, you can apply Rust-Oleum 769 Damp-Proof Red Primer directly over the rusted surface after scraping and wirebrushing to remove rust scale and loose rust. Thus—you save time, labor, and money as costly surface preparations are usually eliminated.

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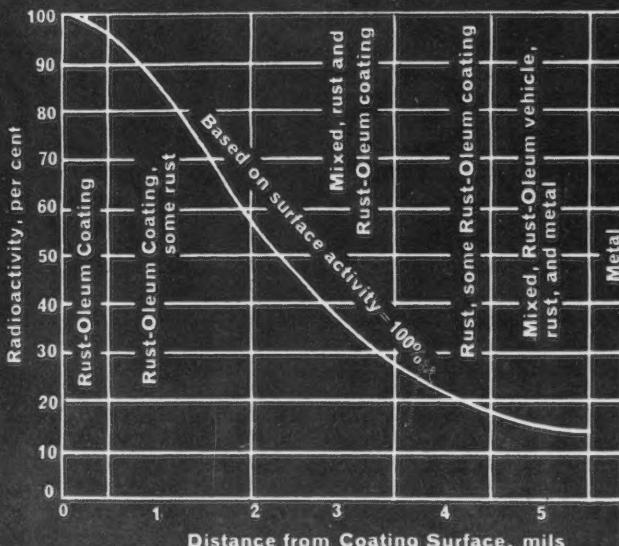
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Photomicrograph (enlarged 250 times) of cross-section of rusted metal coated with Rust-Oleum.

Actual unretouched photomicrograph (enlarged 250 times) showing cross-section of rusted metal coated with Rust-Oleum. Geiger Counter readings were taken at each half-mil level down through the rust—tracing Rust-Oleum penetration through rust to bare metal.

Graph (at right) shows Gas Flow Proportional Counter and Geiger Counter recordings of Rust-Oleum penetration.

Rust-Oleum penetration is expressed in terms of "Percentage of Surface Radioactivity" figures at given mil levels. Note how Rust-Oleum pigment and fish oil vehicle combined penetrate to approximately four mils—then the fish oil vehicle penetrates through remaining rust to bare metal.



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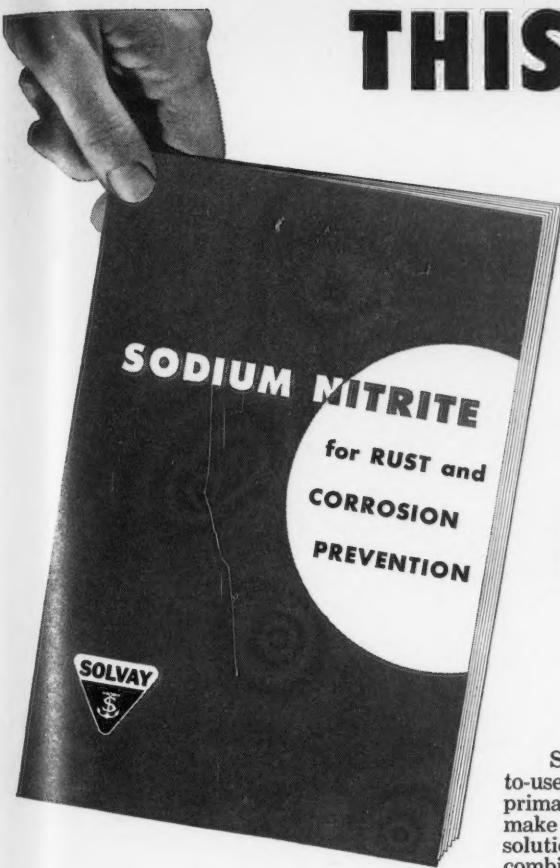
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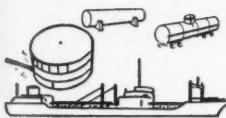
October, 1955

CORROSION—NATIONAL ASSOCIATION OF CORROSION ENGINEERS

11



A Few Typical Applications



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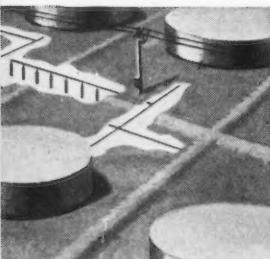
Man from Anaconda—or your Distributor—for full information. Also—write for Bulletin DM 5450: "Anaconda Cathodic Protection Cable." Anaconda Wire & Cable Company, 25 Broadway, New York 4, New York.

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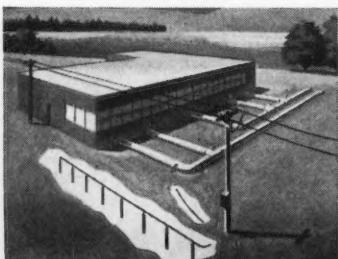
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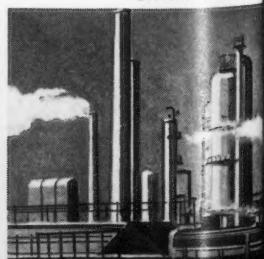
Booster stations



Pipe lines



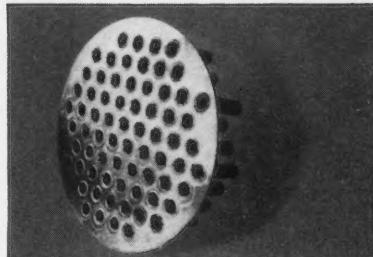
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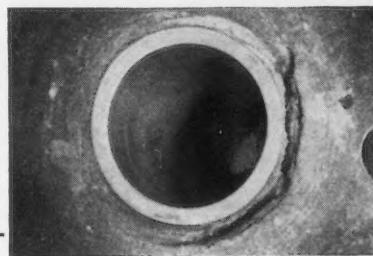
TITANIUM

SOLVES TOUGH CORROSION PROBLEMS

HOT NITRIC ACID at pressures of 300 psi took a high toll of stainless-steel condenser tubes at a Du Pont plant—until this titanium "top-hat" was installed. Fabricated entirely of titanium, it provides a protective sleeve inside the top 3 inches of the condenser tubes. The unretouched photo shows the clean, uncorroded appearance of the "top-hat" after 14 months' continuous service. The titanium tube sheet, tubes and welds have essentially the same appearance as when installed . . . show evidence of being able to serve indefinitely.



HIGH-VELOCITY STEAM and biting hydrochloric acid were cutting the service life of cast-iron steam diffusers to less than 3 months at a Du Pont Pigments plant. Bronze and corrosion-resistant alloys were tried, without improvement. Then a diffuser fabricated from titanium was installed. This proved to be the answer. The photo shows the condition of the titanium diffuser after 2 years' service—a period ten times the average life of other diffusers. Compare the uncorroded appearance of the titanium diffuser with the cast-iron flange, which shows severe acid attack.



A partial list of other environments where TITANIUM offers unmatched corrosion resistance...

CORROSIVE CHEMICALS

Ferric Chloride
Sodium Chloride

CONDITIONS

0-30% at 100° C.
All Conc. at 100° C.

POSSIBLE APPLICATIONS

Process piping
Kettles, heat exchangers

Chlorine-Saturated Water
Wet Chlorine Gas

Room Temperature
75° C.

Proportioning equipment
Recovery equipment,
electrolytic cells

Chromic Acid

10% and boiling

Plating equipment

Sulphuric-Nitric Acid
Mixture

40% sulphuric, 60%
nitric at 35° C.

Acid heaters, nitrators,
auxiliaries

Calcium Hypochlorite

6%-35% C.

Filter presses,
processing equipment

Zinc Chloride

20%-100% C.

Coils, pans, evaporators

TITANIUM MAY BE THE ANSWER TO YOUR CORROSION PROBLEM

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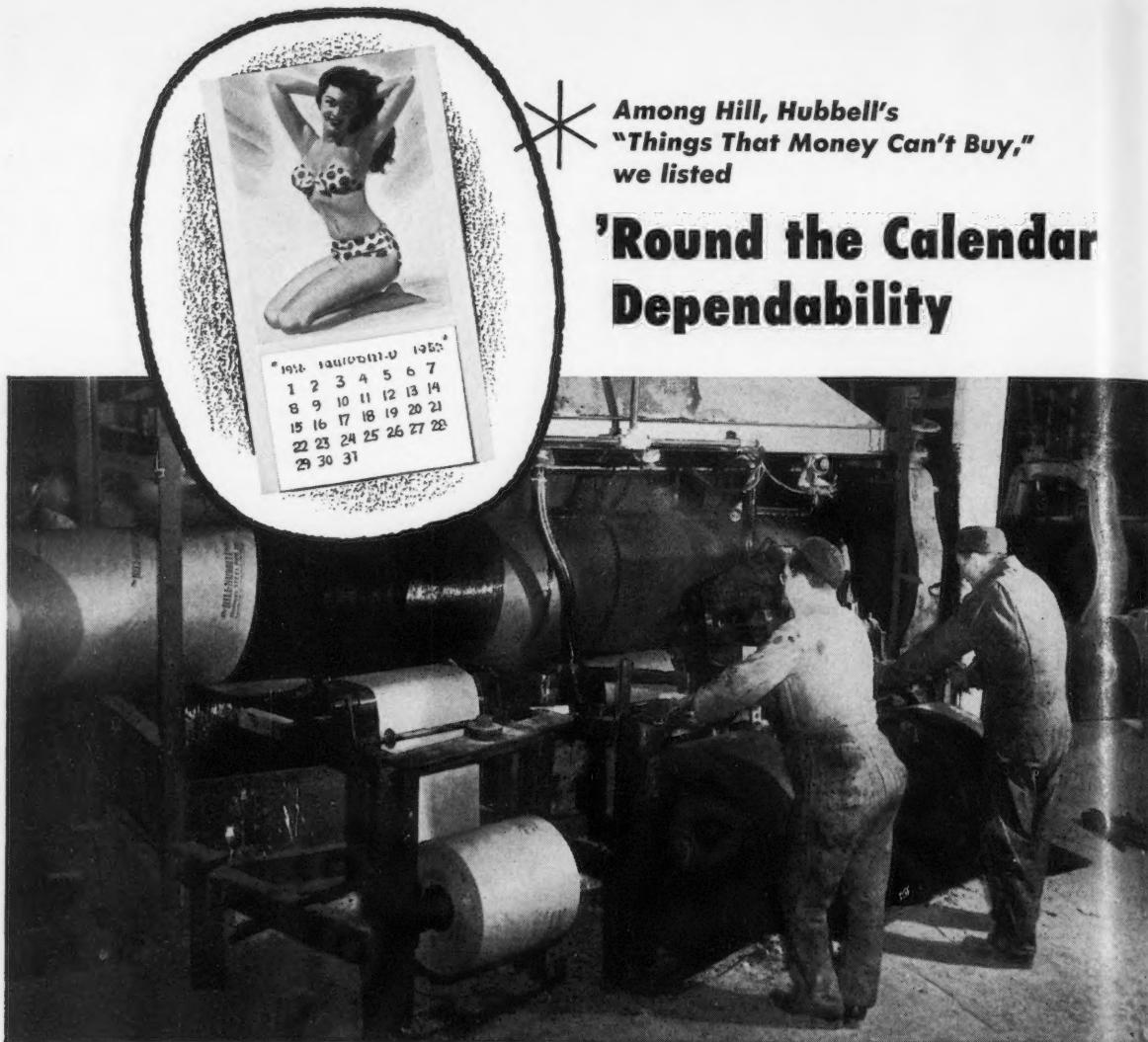
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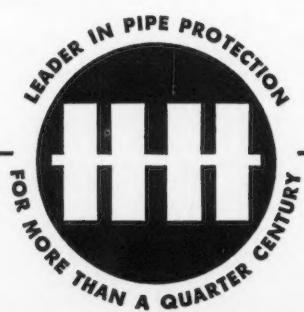
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CORROSION FACTORS		HIGH TEMPERATURE WORK SHEET		
1. PROCESS OR OPERATION: (e.g., heat treating, vitreous enameling, hydrocarbon reactions, etc.)				
2. HEATING PRACTICE: Analysis of fuel.				
Temperature °F. or °C. Maximum.....	Average.....	Rate of heating.....	Standby.....	Date.....
Time at temperature.....				
Method of cooling (e.g., furnace cool, oil quench, etc.).....				
Frequency of heating and cooling.....				
Magnitude of operating stress.....				
3. ENVIRONMENT: Chemical composition of atmosphere, fused salt, molten metal, etc. in contact with metal surface.				
In the case of an atmosphere, give dew point.....				
Concentration of sulfur compounds, if any, preferably in grains sulfur per 100 cu. ft. of air.....				
EQUIPMENT				
4. EQUIPMENT OR PART: (e.g., radiant tube, etc.)				
5. METAL OR ALLOY OR OTHER MATERIAL USED:				
6. DIMENSIONS: Size and thickness of rod, sheet, plate				
EXPERIENCE				
7. SERVICE LIFE OF MATERIAL USED:				
8. TYPE OF FAILURE: (e.g., cracking, sagging, general scaling, etc.)				



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The High Temperature Work Sheet has been designed to make it easy for you to outline your problem as completely as possible and to make sure no significant factors will be overlooked. The completed form will assure your receiving information most applicable to your particular requirements.

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is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

- (a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.
- (b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.
- (c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.
- (d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.
- (e) To promote standardization of terminology, techniques, equipment and design in corrosion control.
- (f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.
- (g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.
- (h) To invite a wide diversity of memberships, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 1061 M & M Building, No. 1 Main Street, Houston 2, Texas.



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Topic of the Month

Surface Pipe Effect— Cathodic Protection of Oil Well Casing

By JACK P. BARRETT*

THE USE of cathodic protection for the prevention of external corrosion on oil well casing is being considered by many operators. Of major concern to those contemplating using this method is the "surface pipe effect."

The potential profile curve obtained on a well under cathodic protection often will show an abrupt anodic slope at the base of the surface pipe. A similar effect has been observed as much as 1000 feet above the bottom of the surface pipe. This is defined as the "surface pipe effect." Figure 1 shows such an effect on the potential profile curve obtained in a West Texas well. The dotted curve shown in this figure is a hypothetical one added to aid the reader in visualizing the effect under discussion.

If this effect is due to electrolytic conductance, then accelerated corrosion would be expected to occur at this point. If the effect is due to metallic conductance with the two casing strings being in contact at this point, then no corrosion should result from this transfer of current.

Several points have been advanced against the theory of electrolytic conductance:

- 1) A large percentage of the profile curves analyzed shows that this surface pipe effect occurs well within the annulus between the surface pipe and the next smaller string of casing.
- 2) Changing the level of the electrolyte in this annulus has no effect on the height at which the current discharge occurs.
- 3) Calculations involving the tension held on the inner casing, sizes and clearances of the two casing strings, and the curvature of the axis of the hole show that the collars of the inner string may contact the surface pipe with considerable pressure.

The above points support a strong argument against electrolytic conductance being the cause of the sur-

face pipe effect and it appears that there is no reason to expect accelerated corrosion at the base of the surface pipe from this cause.

Opportunities for visual inspection of casing with a known potential profile history are rare; therefore, the following example is considered noteworthy.

In June 1952 a string consisting of 5½-inch OD, 14-pound casing was run in a West Texas well. This casing was inspected carefully and all surface imperfections on the pipe were noted. The well was completed at a depth of 4650 feet with natural mud in the annulus from approximately 3900 feet to the surface.

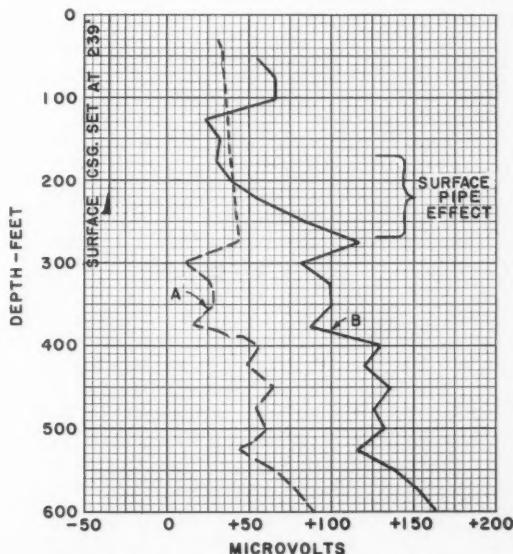


Figure 1—Casing potential profile showing surface pipe effect at base of surface string. Notes: Polarity and depth shown for bottom contactor. 25-foot spacing between contactors. A—Hypothetical curve without surface pipe effect. B—Actual profile with surface pipe effect.

*Research Group Supervisor, Stanolind Oil and Gas Co., Tulsa, Okla.

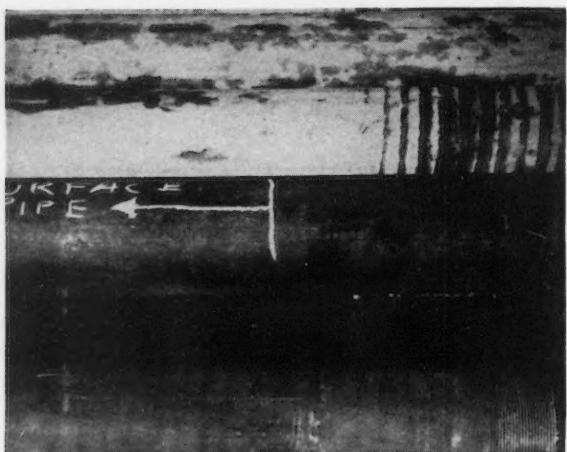


Figure 2—Chalk line shows where the oil string emerged from surface string. Joint at bottom of picture is the first joint below surface pipe. Notice complete absence of attack on these two joints, typical of the 90 feet of casing in the interval where the surface pipe effect was measured.

After one month the well was placed under cathodic protection and a potential profile was run (Figure 1, Curve B). This profile showed that the well was only partially protected and that a surface pipe effect of 70 microvolts was present, corresponding to a current

flow of 0.175 amperes from the inner string to the surface pipe.

In February 1954 prior to pulling the casing, the well was resurveyed and the same surface pipe effect was present. Considering that this current was active for 19 months on 90 feet of pipe, considerable corrosion should have occurred if electrolytic conductance were the mechanism.

Visual inspection of the pipe showed no evidence of accelerated attack on the pipe in the area showing the surface pipe effect. Figure 2 shows the inner string at the place where it emerged from the surface pipe and also the first full joint below this point.

Scale typical of that formed by cathodic protection was found in scattered areas over the entire 1400 feet of pipe recovered. Some slip and tong marks showed minor corrosion occurring with sulfide scale present. Other marks were filled with cathodic scale and corresponded to their initial condition as run in the well. The absence of significant corrosion and the presence of cathodic scale indicate that cathodic protection was effective to a depth of at least 1400 feet and that the surface pipe effect did not cause an accelerated corrosion attack.

It appears that the abrupt anodic slope, or surface pipe effect is caused by the two strings of casing being in contact with one another at the bottom of the surface string or at points above this level.

TECHNICAL PAPERS ON CORROSION WELCOMED

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The Effect of Martensite on Sulfide Stress Corrosion Cracking*

By M. F. BALDY and R. C. BOWDEN, JR.

Introduction

MANY RAPID FAILURES of tubing and other oil well apparatus, both plain carbon and alloy steels, have been experienced in sour condensate wells. Analysis of the gas from these wells shows that they contained hydrogen sulfide and carbon dioxide. Extensive laboratory and field investigations by petroleum producers of both the failed material and possible substitutes seem to justify the conclusion that failures were caused by sulfide stress corrosion cracking.

It was shown in these investigations,¹ that the steels commonly used for API Grades J-55 and N-80 pipe were equal to or better than low alloy steels under conditions of stress and exposure to hydrogen sulfide. The susceptibility of steel to this environment was suspected to be due to the presence of martensite in the structure. However, if the combination of steel composition and heat treatment was such as to eliminate or sufficiently temper the martensite, while still retaining the necessary strength levels, the chance of failures under these conditions should be retarded or prevented.

An investigation into the problem of the effect of microstructure on sulfide stress corrosion cracking was initiated. The initial phase of the program was limited to the study of the effect of martensite on the resistance of steel of the chemical composition used in API Grade N-80 to sulfide stress corrosion cracking. By heat treatment, various percentages of martensite were to be produced in test bars of this grade steel and tested at various stress levels in water saturated with hydrogen sulfide and carbon dioxide. The results of these tests would show the effect of a martensitic structure on the susceptibility to sulfide stress corrosion cracking. Should the effect be deleterious, these tests possibly would reveal in what amounts or in what pattern this structure would have to be present to be damaging.

Test Procedure

Test bars 10 inches long by 0.225 inch square were cut from 0.446-inch wall Grade N-80 pipe of the three following analyses (see Table 1) to cover a spread in analysis.

All sections of pipe were given a full anneal before samples were cut so that all samples would have a

TABLE 1—Composition of Test Bars

	C	Mn	P	S	Mo
Series A.....	.37	1.45	.015	.023	.16
Series B.....	.42	1.65	.020	.023	.18
Series C.....	.41	1.54	.015	.023	.16

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M. F. BALDY—Research Metallurgical Engineer with the National Tube Division, Research Laboratory, United States Steel Corporation. He became associated with the Edgar Thomson Works of the United States Steel Corporation shortly after receiving a BS in Metallurgical Engineering in 1948 from Carnegie Institute of Technology. From 1949 to 1952 he was with the Metallurgical Section of the Weirton Steel Co., Weirton, W. Va. He is a member of the American Society for Metals.



R. C. BOWDEN, JR.—Research Chemical Engineer with the National Tube Division, Research Laboratory, United States Steel Corporation. He received a BS in Chemistry from the University of Pittsburgh in 1941; shortly after that he joined the Chemical Department of the Jones and Laughlin Steel Corporation, By-Products Department, where he served until 1948. He is a member of the National Association of Corrosion Engineers, the American Society for Metals, and the American Chemical Society.

Abstract

Rapid failures of tubing in sour condensate wells have led to an investigation of possible causes of these failures. The presence of hydrogen sulfide points to sulfide stress corrosion cracking as the cause. The effect of untempered martensite was studied as to its bearing on the susceptibility of steel to sulfide stress corrosion cracking.

Test bars from API Grade N-80 tubing previously annealed were heated into the austenitizing range, furnace cooled to temperatures above, within, and below the transformation range, and then water quenched. Over this range of pre-quenching temperatures, samples were produced having from 0 percent to 100 percent martensite. After machining to final size, test bars were two-point beam loaded, with a constant moment between loading points, and immersed in a bath of distilled water saturated with hydrogen sulfide and carbon dioxide. All samples were loaded to various stress levels below the yield strength.

The susceptibility of steel of the chemical composition commonly used in API Grade N-80 pipe (80,000 psi minimum yield strength) to sulfide stress corrosion cracking under these conditions was found to fall into three categories, depending on the percentage of martensite present.

1. From 0 percent martensite to between 30 percent and 35 percent martensite, the steel is not susceptible.

2. From 30 percent to 35 percent up to 75 percent to 80 percent martensite, the permissible applied stress to avoid failure decreases with increase of this phase.

3. Over 75 percent to 80 percent martensite, apparently any applied stress will cause failure.

It was found that when martensite begins to show evidence of continuity in the microstructure, the steel becomes susceptible to sulfide stress corrosion cracking.

similar microstructure at the beginning of the test. The annealing cycle consisted of heating to 1475 F,

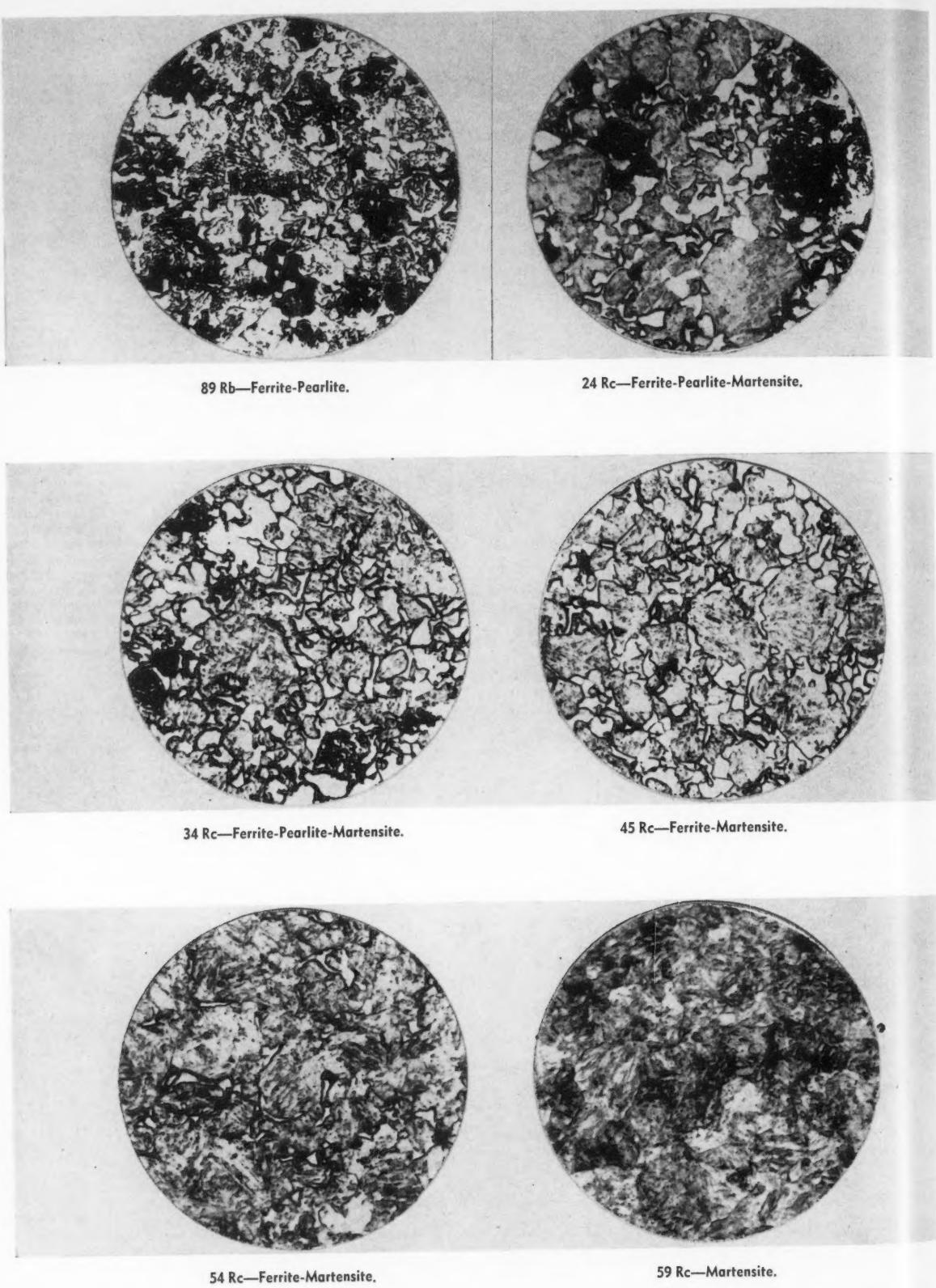


Figure 1—A representative sampling of microstructures found in tests. Martensite etch. 1000 X.

holding for 20 minutes, then furnace cooling to 1250 F; holding at this temperature for two hours, then furnace cooling to room temperature. This treatment produced a structure of ferrite and coarse pearlite with a tendency toward spheroidization.

The test bars were then heated to 1500 F in an electric furnace, held at temperature for 20 minutes, and furnace cooled to furnace temperatures ranging from 1170 F to 1280 F, then water quenched. Two additional samples were heated to 1500 F, held for 20 minutes at this temperature, and water quenched. This produced a series of test specimens ranging in martensitic structure from 0 percent to 100 percent; see Figure 1 for a representative sampling of microstructures. (The etch used was Vilella's reagent—95 cc ethyl alcohol, 1 gm picric acid, 5 cc HCl.) These test bars were subsequently ground to the finished size of 10 inches x 0.200-inch square to remove scale and decarburization.

In order to determine the relationship between hardness and percent of martensite, a total of 28 samples, representing the analyses of steels in Series A, B, and C, and covering the range of pre-quenching temperatures, were examined under the microscope and the percent martensite evaluated. The hardness was then determined using the Rockwell C (Rc) scale. Results are listed in Table 2; a curve of percent martensite versus Rc hardness is shown in Figure 2.

After machining, the samples were polished with 00 emery paper, degreased with ether and two-point beam loaded (two to a bracket) as shown in Figure 3. These samples subsequently were immersed in distilled water saturated with hydrogen sulfide and carbon dioxide. The bracket is a section of steel fitted with two nuts and headless bolts at each end. Near the top of each bolt there is a hole to receive the ends of the test specimen and an insulating layer of rubber. The sample is then stressed by uniformly tightening the nuts on the underside of the bracket which bends the sample over a 4-inch long by $\frac{1}{4}$ -inch thick glass plate centered between the two end clamps. The specimen is insulated from the bracket to prevent galvanic corrosion. The top of a specimen loaded in this manner is in uniform fiber stress between the points of contact with the glass plate. The applied stress is dependent on the clearance between the glass plate and specimen midway between the loading points according to the formula:

$$Y = \frac{L^2 S}{4hE}$$

where:

- Y = deflection at center of beam
- S = stress applied
- L = distance between loading points
- h = height of beam
- E = modulus of elasticity of steel

A thickness gauge was used to measure the deflection at the center of the test bar. Comparison of the calculated stress based on thickness gauge readings against stresses measured by electric strain gauges showed the two to be equal over the stress levels employed.

All samples were loaded to stress levels below the yield point to avoid plastic deformation. The yield point varied depending on the temperature from

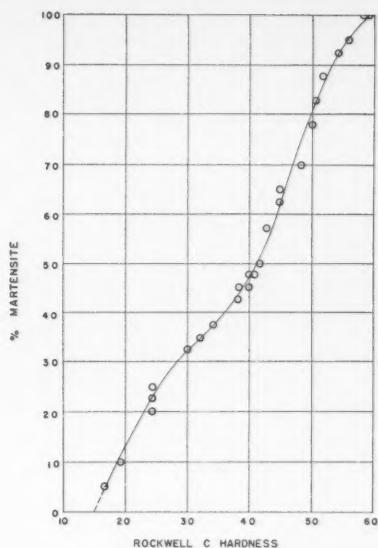


Figure 2—Curve showing percent martensite versus Rc hardness.

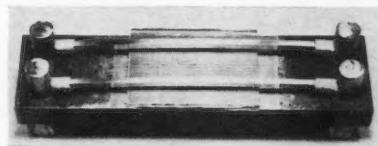


Figure 3—Bracket holding two stressed specimens before immersion into H_2S , CO_2 saturated solution.

which the sample was quenched. Tensile tests were made on samples from Series A and B which were heat treated in the manner described earlier to cover a range of hardness values. These two series give the maximum and minimum values to be expected. A list of the results is presented in Table 3 and a curve of the Rc hardness versus yield strength, in Figure 4. It is evident that the yield strength at the lower hardness levels is due to an abnormal microstructure resulting from the artificial heat treatment and is below the minimum for API Grade N-80 pipe.

Samples were immersed in the bath which was at room temperature (see Figure 5). Immersion was continued until failure occurred as shown in Figure 6, or until such time (from 100 to 300 days) as the samples were removed for microexamination. Once

Table 2—Percent Martensite Versus Rockwell C Hardness

Percent Martensite	Rockwell C Hardness	Percent Martensite	Rockwell C Hardness
5.....	17	45/50.....	41
10.....	19	50.....	42
20.....	24	50.....	42
25.....	24	55/60.....	43
20/25	24	60/65.....	45
20/25	24	65.....	45
30/35.....	30	70.....	48
35.....	32	75/80.....	50
35/40.....	34	80/85.....	51
40/45.....	38	85/90.....	52
45.....	38	90/95.....	54
40/45.....	38	95.....	56
45/50.....	40	100.....	58
45.....	40	100.....	59

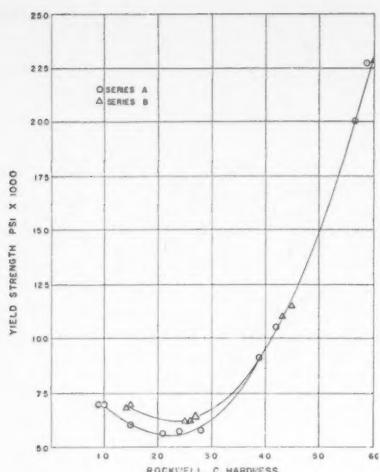


Figure 4—Rc hardness versus yield strength.

TABLE 3—Results of Hardness and .250-Inch Diameter Tensile Tests

Steel Series	Rockwell Hardness	0.2 Percent Offset or Beam Yield Point*—psi	Ultimate Strength psi	Percent Elong. in 1"	Percent Red. of Area	Remarks
A.....	89 Rb	67,150*	95,100	30	66.0	Full Anneal
B.....	93 Rb	75,700*	106,250	27	62.6	Full Anneal
A.....	9 Rc	68,950*	97,900	31	63.5	.....
A.....	10 Rc	68,050*	96,650	27	59.2	.....
B.....	14 Rc	68,100*	107,000	19	38.9	.....
A.....	15 Rc	60,700	100,750	20	42.8	.....
B.....	15 Rc	69,550*	109,700	19	37.0	.....
A.....	21 Rc	56,000	108,800	15	30.0	.....
A.....	24 Rc	57,300	115,750	11	24.8	.....
B.....	25 Rc	61,800	113,750	4	9.8	.....
B.....	26 Rc	61,800	119,550	4	6.3	.....
B.....	27 Rc	63,500	125,100	3	6.7	.....
B.....	27 Rc	63,700	128,450	3	5.5	.....
A.....	28 Rc	57,200	115,250	8	18.6	.....
A.....	39 Rc	90,300	157,880	..	....	Broke in fillet
A.....	42 Rc	104,300	175,550	..	....	Broke in fillet
B.....	43 Rc	109,600	174,950	..	....	Broke in fillet
B.....	45 Rc	114,200	181,600	..	....	Broke in fillet
A.....	57 Rc	200,000	.....	..	....	Broke in threads
A.....	59 Rc	227,500	.....	..	....	Broke in threads
B.....	60 Rc	228,500	.....	..	....	Broke in threads

* Top of Beam.

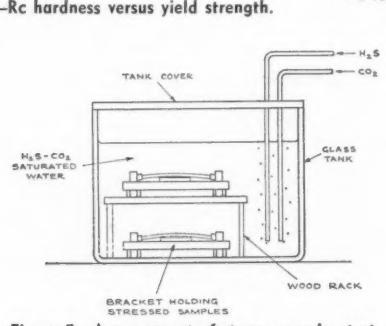


Figure 5—Arrangement of stress corrosion testing apparatus.

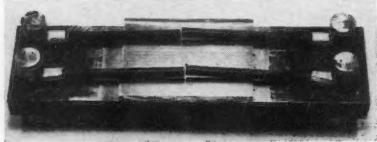


Figure 6—Bracket holding two specimens which failed after exposure in H2S, CO2 solution.

a week the samples were cleaned with a stiff bristled brush to remove any protective film of corrosion products. The tank itself also was cleaned each week and fresh distilled water added which was then saturated with hydrogen sulfide and carbon dioxide before reimmersing the samples.

During the earlier part of the experiment, the tank was uncovered because it was felt that the constant bubbling of hydrogen sulfide and carbon dioxide through the bath would keep it saturated with these gases. The rate of attack on both test specimens and brackets was high at this time. It was decided that this was due to the bath absorbing oxygen from the air. The tank was then tightly covered, and the excess gas bubbling through the system prevented air from coming into contact with the bath and the corrosion rate greatly decreased. It was found that the susceptibility of a given test to failure was due to its microstructure and stress level and was independent of the general corrosion rate.

The curves of percent martensite versus applied

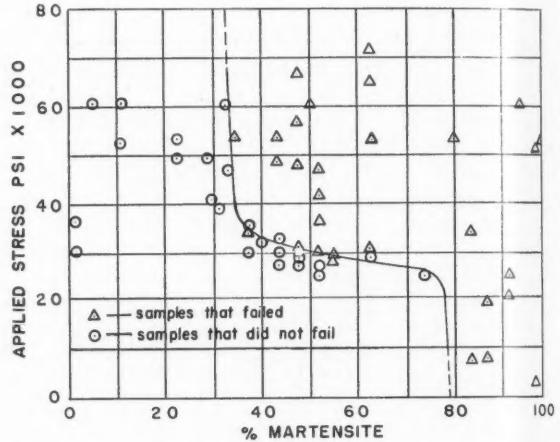


Figure 7—Curve showing percent martensite versus applied stress (as pounds per square inch).

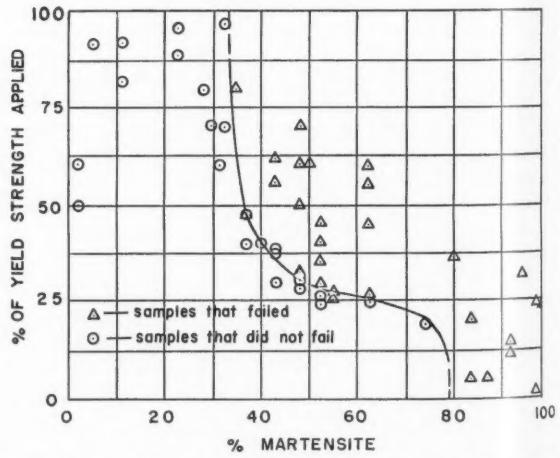


Figure 8—Curve showing percent martensite versus applied stress (as a percentage of the yield stress).

stress, given both as pounds per square inch and as a percentage of the yield stress, are presented in Figures 7 and 8. These are taken from the data in

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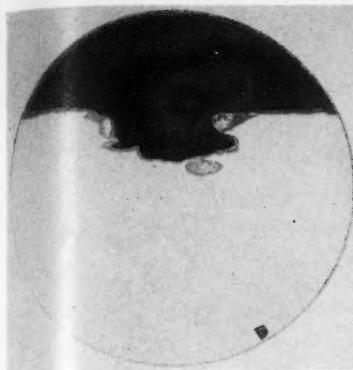


Figure 9—Macrograph of longitudinal cross section of Rc 24 sample exposed to H₂S environment. After 300 days exposure at 95.9 percent of the yield strength, sample showed corrosion but no cracking. No etch. 19 X.

Table 4 which include tests made before and after covering the tank. The hardness values given in Table 4 were converted to percent martensite before the curves in Figures 7 and 8 were drawn. This was done using the curve of percent martensite versus Rc hardness presented in Figure 2.

All points on these curves fit into place on the basis of microstructure and stress level only and were completely independent of corrosion rate. An appreciable difference could not be found between steels from the three series of analyses tested. In other words, samples of A, B, and C of equal hardnesses had similar microstructure and susceptibility depending on hardness and stress level.

Results

A list of all the data on specimens immersed in the bath is presented in Table 4. Curves drawn from these data, Figures 7 and 8, of percent martensite versus stress, indicate three zones of susceptibility.

1. The first range includes all samples below 30 percent to 35 percent martensite. These samples did not fail under a series of stress levels which approached the yield point.
2. Samples in the range of 30-35 percent martensite up to 75-80 percent martensite either failed or resisted sulfide stress corrosion cracking, depending upon the applied fiber stress.
3. Samples containing more than 80 percent martensite failed under very low applied stress.

Examination, after exposure of up to 300 days, of samples in the first range showed pitting due to corrosion, but no stress corrosion cracking. (See Figure 9.) It was observed that four of the samples in this group loaded to more than 90 percent of the yield stress had yielded slightly due to relaxation. In order

TABLE 4—Data on Stressed Samples Immersed in H₂S-CO₂ Saturated Water

Sample No.	Rockwell	Yield Strength psi	Applied Stress psi	Percent of Yield Strength	No. of Cleanings	Time to Failure	Total Time in Bath
AS.....	89 Rb	67,150	53,750	80.0	42		300 days
BS.....	93 Rb	75,700	60,550	80.0	42		300 days
BBBB.....	17 Rc	66,000	60,550	91.7	42		300 days
B1.....	19 Rc	64,000	60,550	94.6	42		300 days
B2.....	19 Rc	64,000	52,800	82.5	42		300 days
A8.....	24 Rc	56,000	49,600	88.6	42		300 days
A7.....	24 Rc	56,000	53,700	95.9	42		300 days
B3.....	27 Rc	62,000	49,200	79.4	42		300 days
A26.....	30 Rc	62,000	60,000	96.8	38		270 days
B4.....	30 Rc	67,000	47,000	70.1	42		300 days
C32.....	32 Rc	67,000	53,600	80.0	0	5 days	
A25.....	34 Rc	72,000	34,200	47.5	0	6 days	
AAAA.....	38 Rc	87,000	48,600	55.9	0	16 hours	
AAA.....	38 Rc	87,000	53,700	61.7	0	24 hours	
B20.....	38 Rc	89,000	26,700	30.0	42		300 days
B27.....	38 Rc	89,000	30,000	37.5	38		270 days
A23.....	40 Rc	95,000	30,000	31.6	0	4 days	
A38A.....	40 Rc	95,000	31,000	32.6	0	7 days	
A15.....	40 Rc	95,000	47,500	50.0	0	5 hours	
A9.....	40 Rc	95,000	57,000	60.0	0	4 hours	
A10.....	40 Rc	95,000	66,500	70.0	0	5 hours	
B30.....	40 Rc	96,000	28,800	30.3	38		270 days
BBB.....	41 Rc	100,000	60,550	60.6	0	16 hours	
A24.....	42 Rc	104,000	27,000	26.0	39		275 days
A42.....	42 Rc	104,000	30,000	28.8	0	7 days	
A19.....	42 Rc	104,000	36,400	35.0	0	4 hours	
A17.....	42 Rc	104,000	41,600	40.0	0	5 hours	
A18.....	42 Rc	104,000	46,800	45.0	0	6 hours	
AA42.....	43 Rc	109,000	27,250	25.0	0	7 days	
A28.....	43 Rc	109,000	29,400	27.0	0	24 hours	
A31.....	45 Rc	119,000	29,000	24.4	35		250 days
A32.....	45 Rc	119,000	31,000	26.1	0	24 hours	
B16.....	45 Rc	119,000	53,550	45.0	0	4 hours	
B11.....	45 Rc	119,000	65,450	55.0	0	3 hours	
B12.....	45 Rc	119,000	71,400	60.0	0	3 hours	
B22.....	48 Rc	135,000	25,000	18.5	40		280 days
AA.....	50 Rc	147,000	53,700	36.5	0	18 hours	
B21.....	51 Rc	152,000	30,400	20.0	0	17 hours	
C38.....	51 Rc	152,000	7,600	5.0	0	20 hours	
C36.....	52 Rc	159,000	8,000	5.0	2	8 days	
C35.....	52 Rc	159,000	19,100	12.0	0	2 hours	
A29.....	54 Rc	172,000	25,000	14.5	0	24 hours	
C34.....	54 Rc	172,000	20,000	11.6	0	4 hours	
BB.....	56 Rc	190,000	60,550	31.9	0	6 hours	
A13.....	58 Rc	211,000	50,750	24.1	0	15 min.	
C40.....	58 Rc	211,000	3,000	1.4	0	5 hours	
B14.....	59 Rc	225,000	52,750	23.4	0	13 min.	
C33.....	34 Rc	75,000	30,000	40.0	42		300 days
C37.....	36 Rc	82,000	32,800	40.0	37		265 days
C39.....	34 Rc	75,000	35,250	47.0	35		250 days
1A.....	28 Rc	58,000	40,600	70.0	29		205 days
1B.....	29 Rc	65,000	39,000	60.0	29		205 days
40AA.....	15 Rc	61,000	30,500	50.0	25		180 days
A40A.....	15 Rc	61,000	36,600	60.0	25		180 days
A38.....	38 Rc	87,000	33,000	37.9	15		105 days
A42A.....	42 Rc	104,000	25,000	24.0	15		105 days
AA38A.....	40 Rc	95,000	27,000	28.4	14		100 days

to avoid this, a limit of 85-90 percent of the yield strength should be set on the applied fibre stress.

In the second stage, samples loaded over a "critical" stress, depending on structure, failed, while tests stressed to limits below this "critical" stress did not fail. Microexamination of specimens in this range which did not fail, Figures 10 and 11, revealed many small transverse cracks on the top side of the specimen. These would have the effect of partially relieving the applied stress, thus rendering the steel less susceptible although potentially weakened in inherent strength. Figure 12 shows the root of the crack in Figure 11 which is predominantly transgranular and through the martensitic network.

The final group includes those samples which apparently fail under any applied stress. Figure 13 shows a short time failure from this group and reveals no corrosion or secondary cracking. Figure 14 is a macrograph of a sample which failed after eight days exposure and exhibited many secondary stress

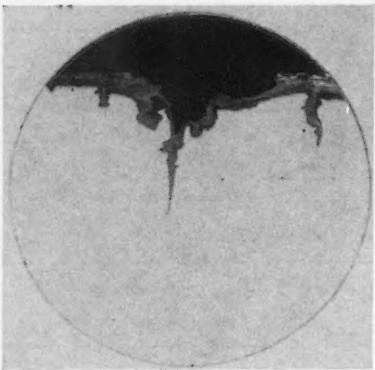


Figure 10—Macrograph of longitudinal cross section of Rc 40 sample exposed to H₂S environment. After 270 days exposure at 30.3 percent of the yield strength, sample showed stress corrosion cracking. No etch. 19 X.

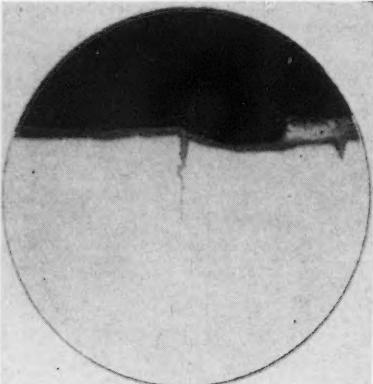


Figure 11—Macrograph of longitudinal cross section of Rc 40 sample exposed to H₂S environment. After 270 days exposure at 30.3 percent of the yield strength, sample showed stress corrosion cracking. No etch. 20 X.

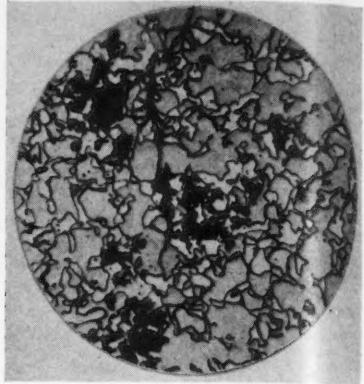


Figure 12—Root of crack seen in Figure 11. Crack is transgranular. Martensitic etch. 806 X.

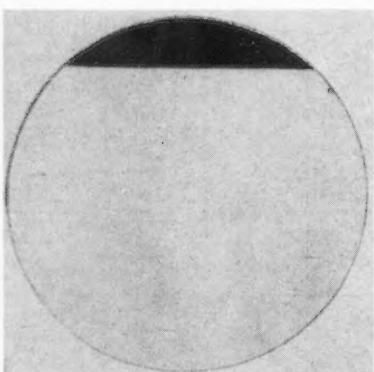


Figure 13—Macrograph of longitudinal cross section of Rc 51 sample exposed to H₂S environment. Sample broke after less than 17 hours exposure at 20.0 percent of the yield strength. No corrosion or cracking was observed. No etch. 19 X.

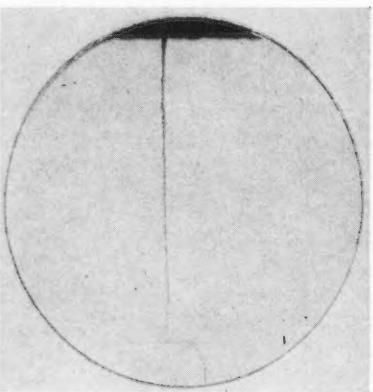


Figure 14—Macrograph of longitudinal cross section of Rc 52 sample exposed to H₂S environment. Sample failed after eight days exposure at 5.0 percent of yield strength. Note stress corrosion cracking. No etch. 20 X.



Figure 15—Root of crack seen in Figure 14. Crack is transgranular. Martensitic etch. 795 X.

corrosion cracks, one of which is shown. Figure 15 is of the base of the above crack and again the crack is principally through the martensite and predominantly transgranular.

Conclusions

Martensite when present as a network of contacting grains in the material tested renders that steel susceptible to sulfide stress corrosion cracking. As the percentage of martensite present increases to near 80 percent, the allowable stress to avoid failure decreases. Martensite present in amounts above 80 percent apparently renders the steel susceptible under any applied stress.

Future Work.

This paper is given as an interim report because of the intense general interest in this subject by both suppliers and users of oil country goods. The conclusions are drawn from the results of laboratory

tests made under controlled conditions which were considered to be severe. An attempt will be made in future work to correlate these results with actual experience in the field.

Additional work is now in progress whereby an attempt is being made to correlate this phenomenon with the known processes of suppliers. Should some correlation be established, efforts will be directed toward process controls or changes so as to assure a product which will resist sulfide stress corrosion cracking and eliminate failures due to this cause.

Acknowledgments

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Reference

1. Symposium on Sulfide Stress Corrosion. *Corrosion*, 8, No. 10, 326-360 (1952) Oct.

Any discussions of this article not published above will appear in the December, 1955 issue.

Geometric Factors in Electrical Measurements Relating to Corrosion and Its Prevention*

By W. J. SCHWERDTFEGER⁽¹⁾ and IRVING A. DENISON⁽²⁾

1. Introduction

BECAUSE of the electrochemical nature of corrosion in aqueous media, the study of current and potential relations pertaining to galvanic couples has provided much useful information concerning the mechanism of corrosion and its prevention. However, relatively little attention has been given to the spatial relations between the anodic and cathodic areas that comprise the galvanic couples. In a given medium, potentials⁽³⁾ are affected by the polarization of the elements of the couple and also by the conductivity of the electrolyte. In order to study the potential pattern around a galvanic couple⁽⁴⁾ most effectively, measurements might be made with the couple in a solution which causes relatively little polarization. The conclusions reached from these measurements, insofar as geometrical considerations are concerned, should also be applicable to all galvanic couples of similar configuration, regardless of polarization or electrolyte conductivity. It might even be true that in certain environments such geometrical considerations become relatively insignificant, for example, in a highly conductive electrolyte producing considerable polarization.

The plan of this investigation was to make an experimental study, based on theory, of the potential distribution in the vicinity of the line electrodes immersed in a conducting medium and to show the relation between the potential pattern and geometry. The relationship was then extended to experimental galvanic couples in the form of cylinders, with the aim of perhaps applying the information obtained to the measurement of potentials on subsurface structures of similar configuration, such as pipelines.

2. Theoretical Considerations

2.1. Definition of Symbols

The electrical symbols used throughout this paper are identified and defined as follows:

- E_a = Open-circuit potential of the anode.
- E_c = Open-circuit potential of the cathode.
- E_g = Potential of the couple.
- ΔE_a = Change in anode potential.
- ΔE_c = Change in cathode potential.
- E_p = Potential at some arbitrary point P.
- E_i = External voltage applied to the couple.
- E = Potential at the electrical boundary of the couple when external current is cathodically applied. For the ex-

Abstract

The "electrical boundary" of a galvanic couple immersed in an aqueous medium, when corroding normally and also when corrosion is stopped by cathodic protection, is discussed in the light of present theory. Experimental data, consisting of potential measurements made on bimetallic couples in an unrestricted medium producing relatively little polarization and also one producing considerable polarization, are compared with theoretical data. The electrical boundary is theoretically defined and experimentally verified for model galvanic couples having bimetallic electrodes, one couple simulating line electrodes and the others having electrodes made of longitudinal cylindrical segments arranged in three anode-to-cathode area ratios. The effect on potential measurements as a result of interference to the normal flow of galvanic and external currents is also shown by experimental data. The results of this study indicate that geometric factors should be given consideration in making potential measurements on subsurface structures of similar configuration, such as cylindrical tanks and pipelines.

perimental data in this paper, E is associated with the current I_p .

- e_a = Anode (surface) driving potential.
- e_c = Cathode (surface) driving potential.
- E_c = Potential of the cathode during cathodic protection.
- I = External current to the couple.
- I_p = External cathodic current flowing to the couple when the cell current is $i_o = 0$, defined as the current necessary for cathodic protection.
- i_o = Cell current.
- R_g = Resistance of the couple to the flow of external current.
- r_a = Electrolytic anode resistance.
- r_c = Electrolytic cathode resistance.
- $r_o = r_a + r_c$ = Electrolytic cell resistance.
- r_s = Electrolytic resistance external to the electrical boundary.

2.2. Galvanic Couple Without External Current

When the anode and cathode of a galvanic couple do not polarize the following relation applies:

$$E_c - E_a - i_o r_o = 0 \quad (1)$$

If the anode and cathode do polarize and the cell resistance r_o is expressed in terms of its anodic and cathodic components, eq (1) becomes

$$e_c - e_a - i_o r_a - i_o r_c = 0 \quad (2)$$

or

$$e_a + i_o r_a = e_c - i_o r_c = E_g \quad (3)$$

Equation (3) is pictured diagrammatically in Figure 1.

If a reference electrode is dipped into the electrolyte in the vicinity of the couple and moved from the anode surface to the cathode surface, the measured potential, E_p , between the reference electrode and the couple will vary from e_a through E_g to e_c . If the reference electrode is sufficiently far removed from the couple so as to be out of the influence of the anode and cathode, the potential measured will be E_g in all positions. The variation in potentials observed will depend chiefly on the difference between

* Reprinted from *J. Res. NBS*, 54, No. 2, 61-71 (1955) Feb.

(1) National Bureau of Standards, Washington, D. C.

(2) At present with the Diamond Ordnance Fuze Laboratories, Dept. of Defense, Washington, D. C.

(3) The term "potential" as used in this paper implies a difference of potential between a standard reference electrode and the element under discussion in the same electrolyte. When current flows, resistance drop is included.

(4) The term "galvanic couple" implies the flow of current produced locally by cell action due to the contact of dissimilar metals in a certain environment or because of the environmental effect on different areas of the surface of a metal.

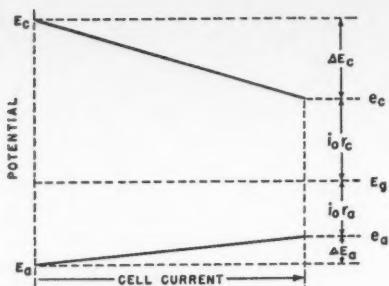


Figure 1—Electrical relations in a galvanic couple.

the open-circuit potentials, E_a and E_c , and the polarization, ΔE_a and ΔE_c , after the couple is formed.

A better understanding of the couple potential is possible if one imagines two line electrodes, A and C, of infinite length surrounded by an unbounded electrolyte, as shown in Figure 2a disregarding the circle for the present. If a current is flowing between anode A and cathode C, the potential, E_p , at some point, P, is expressed spatially by the function $\log \rho_2/\rho_1$, as illustrated in Figure 2b,¹ where ρ_1 and ρ_2 are, respectively, the distances between the anode and the cathode and point P. If, for example, the line electrodes are separated by a distance of 2.25 inches, the potential variation along the AA' axis with respect to the intersection of the AA' and BB' axes would be as shown in Figure 2b. It will be noted that the potential, E_g , is approached asymptotically by values measured along the AA' axis, as indicated, or on all axes other than BB', which is an equipotential axis equal to the potential of the couple. For the non-polarized line electrodes shown,

$$E_g = \frac{E_a + E_c}{2} \quad (4)$$

For a condition of polarized line electrodes, the expression becomes

$$E_g = \frac{e_a + e_c}{2} \quad (5)$$

If the couple elements are no longer in the form of line electrodes, the couple potential, E_g , in relation to e_a and e_c will depend on the relative values of r_a and r_c (Figure 1).

2.3. External Current Applied to a Cylindrical Conductor

If an equipotential cylindrical surface of infinite length (Figure 2a), disregarding the couple AC, is surrounded by an unbounded electrolyte, the electrical resistance of the cylinder to the radial flow of current is expressed geometrically by the function $\log D/a$, where D and a are both in the same units, D being the radius of a concentric circle and a the radius of the cylindrical conductor.² Therefore, if the conductor is subject to a radial flow of direct current, it will be surrounded by concentric equipotential circles and the potential, E_p , along any radius will vary as the function $\log D/a$, assuming that the current is constant and the potential of the conductor does not change during the course of the measurement. It will be shown (experimentally) later that this approximates the potential distribution at some distance

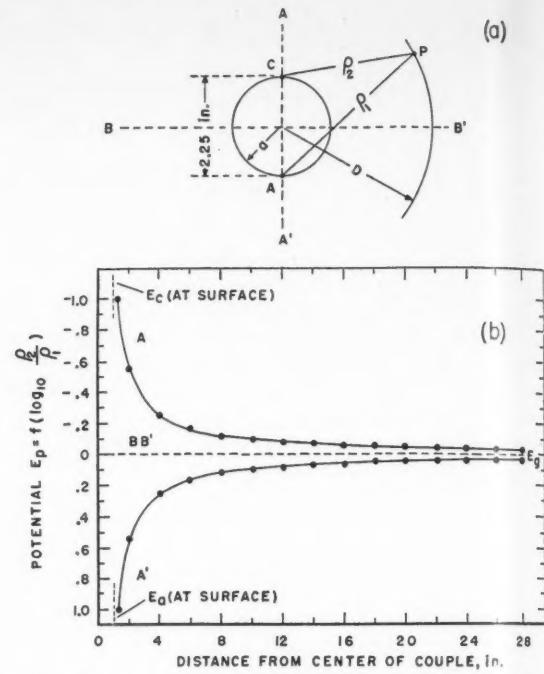


Figure 2—Theoretical potential of non-polarized line electrodes.

away from a galvanic couple in the form of a cylinder under the condition of an externally applied current.

2.4. Effective Electrical Boundary

It has been shown that the theoretical potential of a couple is not reached within finite distance, except along the BB' axis. Actually, however, in a given electrolyte, the distance away from the couple where changes in potential, E_p , becomes insignificant is considered as the electrical boundary,³ and the corresponding potential is looked upon as the potential, E_g , of the couple.

It is sometimes desirable to measure the potential of a galvanic couple while an external current is flowing to it. Under such circumstances the electrical boundary, as previously defined, becomes obscured because of the IR drop resulting from the applied current. A simultaneous evaluation of both the local and external current effects might be imagined if one considers the couple and the cylinder (Figure 2a). In Figure 3 are shown the logarithmic potential functions $\log_{10} \rho_2/\rho_1$ and $\log_{10} D/a$ for the couple and cylinder (diameter, 2.25 inches), respectively, plotted against the distance from the intersection of the AA' and BB' axes (center of the couple) as the abscissa. Also, if the abscissa were expressed as multiples of the distance AC (Figure 2a), the resulting curves would be similar to those of Figure 3.

It will be observed that beyond, for example, 14 inches (abscissa) the change in the couple potential function $\log \rho_2/\rho_1$ becomes relatively small in comparison with the change in the cylindrical potential function $\log D/a$. Therefore, if external current flows to the cylinder with the superimposed couple actually in direct contact, the concentric equipotential lines previously discussed in connection with the cylinder

only would be expected, for all practical purposes, to still exist beyond the electrical boundary. The limiting distance of 14 inches, geometrically expressed, is about 6 diameters and might be looked upon as the "effective electrical boundary" of a galvanic couple diametrically superimposed on and in contact with a conducting cylinder of infinite length in an unrestricted electrolytic medium.

The accuracy of the geometric factor 6 as related to the effective electrical boundary can be experimentally evaluated by comparing the potential measured at 6 diameters on a laboratory model with the calculated boundary potential, E , pertaining to the model, based on the work of Holler.^{4,5} Holler has shown that the resistance, R_g , of a galvanic couple, is

$$R_g = \frac{r_a r_c}{r_a + r_c} \quad (6)$$

Thus in Figure 4, when the switch is closed, the following equations apply:

$$E_t + Ir_s - (E_g - IR_g) = 0 \quad (7)$$

Let,

$$E = E_t + Ir_s \quad (8)$$

Then,

$$E = E_g - IR_g \quad (9)$$

the potential at the electrical boundary.

When the applied current, I , is equal to I_p (see definition of symbols), the potential of the anode, A, will be E_a because no current is leaving the anode. When $i_o = 0$, then eq (3) becomes

$$E_g = e_a = E_a \quad (10)$$

and eq (9) becomes

$$E = E_a - I_p R_g \quad (11)$$

E_a and I_p are measurable and R_g can be calculated. In an electrolyte producing relatively little polarization of the electrodes, A and C, after measuring the potential, E_g , the electrode potentials, e_a and e_c , can also be measured by placing the reference electrode adjacent to the anode and cathode surfaces, respectively. The galvanic, or cell, current, i_o , can be measured with a zero-resistance milliammeter. From eq. (3) and Figure 1, it is apparent that

$$i_{o,r_a} = E_g - e_a, \text{ and } i_{o,r_c} = e_c - E_g \quad (12)$$

therefore,

$$r_a = \frac{E_g - e_a}{i_o}, \text{ and } r_c = \frac{e_c - E_g}{i_o} \quad (13)$$

The value R_g can now be calculated and by substituting appropriate values in eq (11), the calculated potential, E , at the electrical boundary might be compared with the value actually measured with the reference electrode supposedly at the boundary.

3. Experimental Results

3.1. Laboratory Methods

The measurements were made in a cylindrical wooden vat approximately 66 inches in inside diameter and 18 inches high. The inner wall of the vat was lined

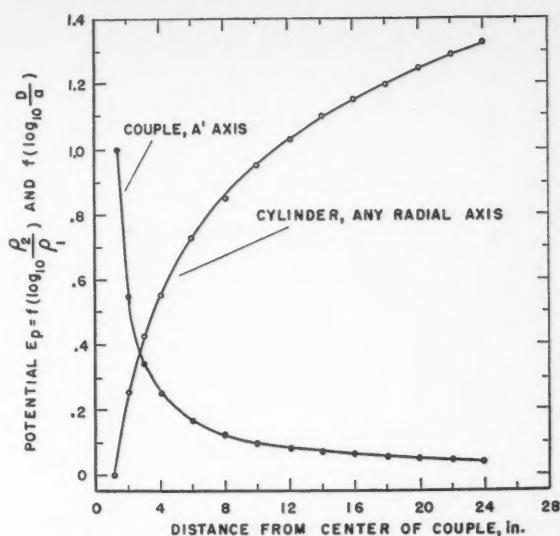


Figure 3—Comparison of the potential of a galvanic couple without external current and the potential around a cylinder receiving current. Data apply for the dimensions in Figure 2a.

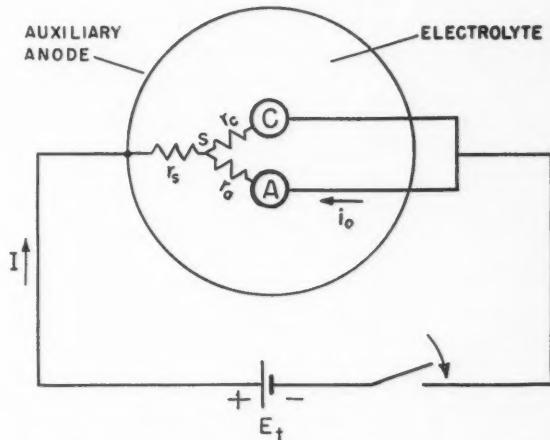


Figure 4—External current applied to a galvanic couple.

with a copper sheet, which served as the auxiliary anode when external current was applied to the experimental cathodes. A $\frac{3}{8}$ -inch steel rod was rigidly mounted off-center across the top of the open vat to hold C-clamps for securing the galvanic couples in the center of the tank perpendicular to the wooden bottom. The rod also facilitated fastening and adjustment of the probe electrode for measurements made along the AA' axis. All potentials were measured with a high-resistance voltmeter (200,000 ohms/volt) and a saturated calomel half-cell terminated in a 8-foot-long flexible plastic tube and probe electrode, both of which were filled with a saturated potassium chloride-agar mixture. All potential measurements were made in a horizontal plane about 2 inches below the surface of the electrolyte in the vat. The electrolyte was maintained in level to a depth about 1 inch from the top of the vat.

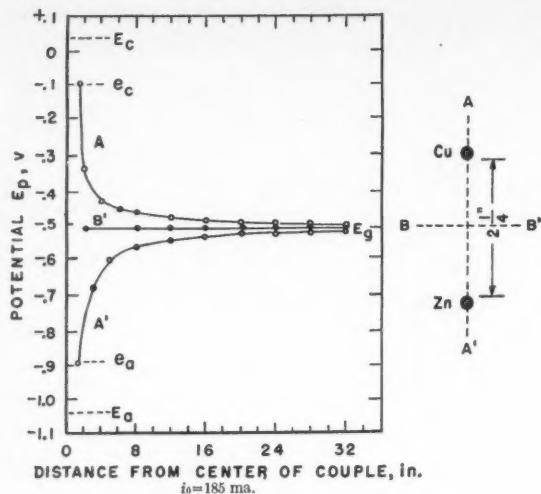


Figure 5—Galvanic couple of line electrodes in a one-tenth normal copper sulfate solution.
 $i_0 = 185 \text{ mA}$.

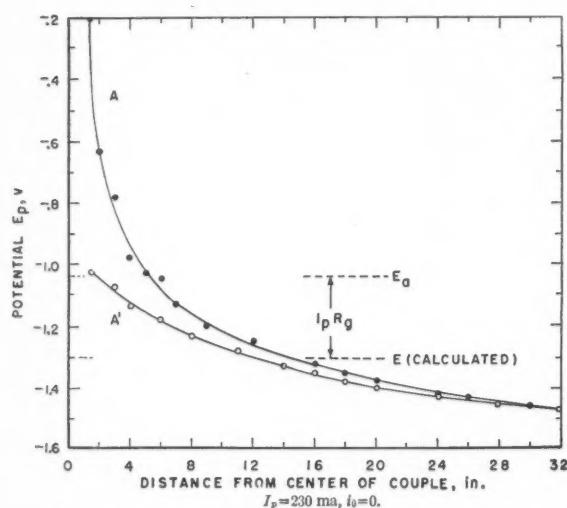


Figure 6—External cathodic current applied to the couple (Figure 5).
 $I_p = 230 \text{ mA}$, $i_0 = 0$.

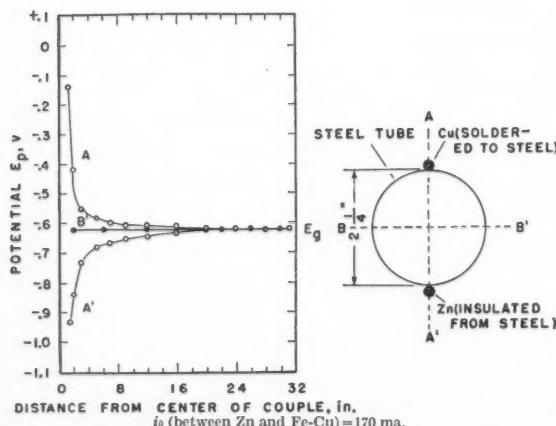


Figure 7—Same as Figure 5 except for the steel tube.
 i_0 (between Zn and Fe-Cu) = 170 mA.

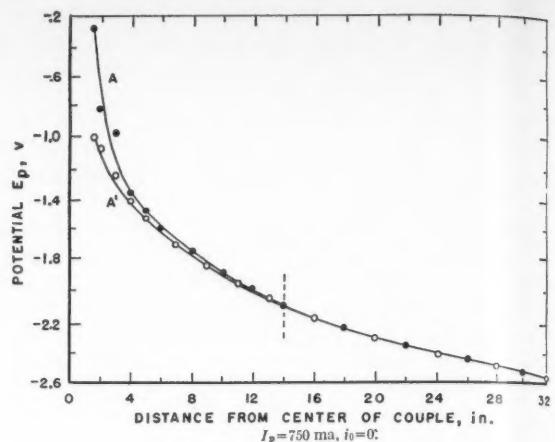


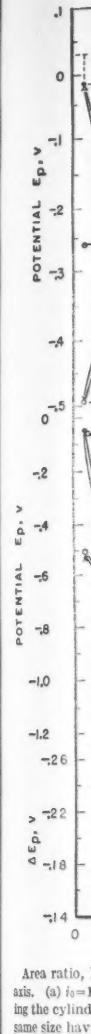
Figure 8—External cathodic current applied to the combination of couples (Figure 7).

3.2. Galvanic Couple of Simulated Line Electrodes in a Dilute Copper Sulfate Solution

The first experiments consisted of observations on galvanic couples having elements of zinc and copper in the form of paired rods of varying diameter in a solution of approximately N/10 copper sulfate. Small-diameter rods (0.125-inch) were the nearest approach to theoretical line electrodes, but it was found that instability prevailed because of polarization due to the large galvanic-current densities, when such rods were coupled. However, rods of $\frac{5}{16}$ -inch diameter or greater were polarized relatively little in the solution and therefore were free from unstable surface effects. Data obtained on a pair of externally short-circuited $\frac{5}{16}$ -inch zinc and copper rods are shown in Figure 5. The rods were separated by 2.25 inches to allow for the insertion later of a 2.25-inch-outside-diameter conducting cylinder between the rods so that the data obtained might be compared with the theoretical diagrams (Figures 2 and 3). It will be noted that 90 percent of the change in potential, attributable to IR drop, between the cathode and anode surface potentials, e_c and e_a , respectively and the couple potential E_g , occurs at 10 inches in either direction along the AA' axis and the intersection with the BB' axis, namely, the center of the couple. This agrees quite well with the theoretical data, Figure 2b. Actually, if the electrodes are to be considered strictly as line electrodes, it would probably be more appropriate to consider their separation as being equal to the distance between their centers, namely, 2.56 inches.

Figure 6 shows potentials measured along the A and A' axes for the same couple, potentials along the BB' axis being omitted, for the condition when the galvanic current $i_0 = 0$, accomplished by applying external current, I_p . The potential, E, at the electrical boundary calculated by the use of eq (11), is shown as one of the dashed horizontal lines in the figure crossing the A' and A curves at 12 and 14 inches, respectively and therefore is in fair agreement with the geometric electrical boundary (6 times distance of separation).

In Figure 7 is shown the effect obtained by insert-



Area ratio, axis, (a) $i_0 = 0$, the cylinder same size have

Figure 9—C

ing a conductor between the electrodes. The rod being 5 and 7 times the size of the other, the potential, E, at the boundary is the same. While the effect only after the electrode detaches from the steel. Although important is the fact that the source in Figure 6, is an open-circuit galvanic

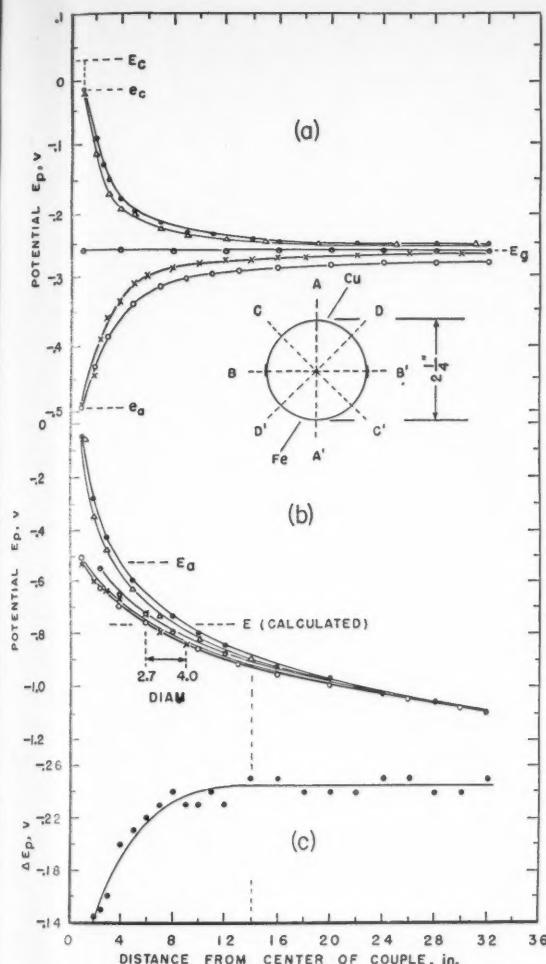


Figure 9—Cylindrical galvanic couple in a one-tenth normal copper sulfate solution.
 Area ratio, Fe:Cu=1:1. ●, A axis; ○, A' axis; □, B' axis; △, D axis; ✕, C' axis. (a) $i_0=125$ ma, $I_p=0$; (b) $i_0=0$, $I_p=250$ ma; (c) Potential pattern surrounding the cylindrical couple compared with that around a uniform cylinder of the same size having the same external current applied.

ing a conducting cylinder (steel tube) between the copper and zinc electrodes (Figure 5), the copper rod being soldered to the steel. In comparing Figures 5 and 7 it will be observed that, as a result, the couple potential, E_g , changed, but the effective electrical boundary of the Zn-Cu couple remained about the same. When external current was applied (Figure 8) the effect of the copper and the zinc became negligible only after 14 inches, showing that the copper electrode determined the electrical boundary, even though the steel was the larger cathodic element of the couple. Although not pertinent to the present discussion, but important from the standpoint of cathodic protection, is the fact that 750 ma, as compared to 230 ma (Figure 6), had to be applied from the external power source in order to reduce the galvanic current to zero. This was so because the inclusion of the steel, having an open-circuit potential of -0.61 v, put the system of galvanic couples under anodic control.

3.3. Galvanic Couples With Electrodes Consisting of Cylindrical Segments in the Dilute Copper Sulfate Solution

In order to determine whether the potential distribution around galvanic couples in the form of cylinders was similar to that in the vicinity of line electrodes, model cylindrical couples were constructed having the same diameter as the distance between the line electrodes discussed in the previous experiments.

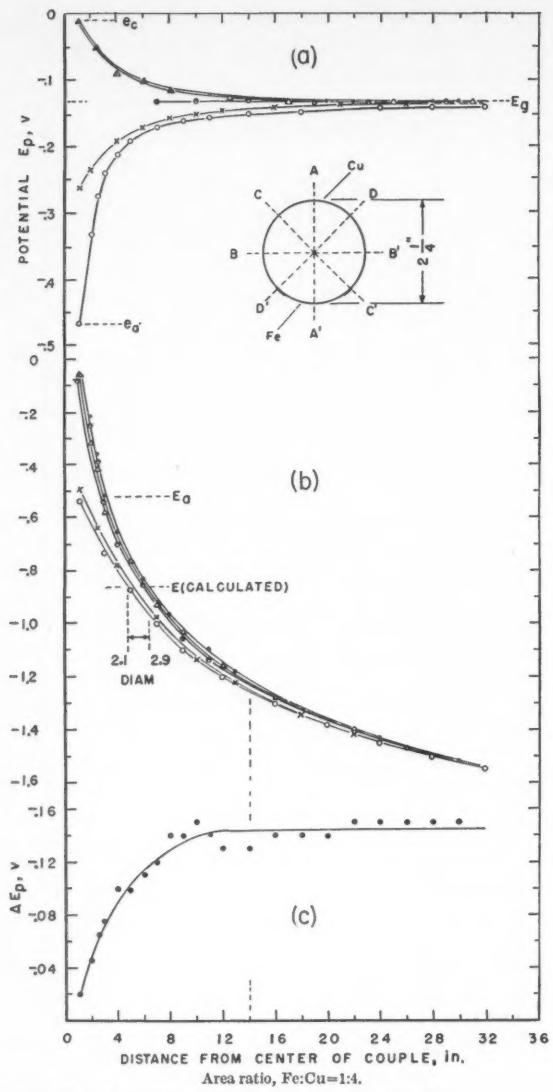
The combination of a galvanic couple and conducting cylindrical surface might be represented by a cylinder having two longitudinal segments of different metals. The experimental models with which the remaining data were obtained consisted of such bimetallic cylinders having three area ratios of steel and copper with insulation between the metals to enable the measurement of galvanic current. Only the exterior cylindrical surfaces were exposed to the electrolyte.

Data obtained on the three cylindrical models are plotted in Figures 9, 10 and 11. In addition to potentials on the AA' and BB' axes, are shown also potentials measured along intermediate axes CC' and DD'. Axis orientation is shown in the inset, part (a) of the figures. The change in potential along the AA' axis (Figure 9a) compares on a percentage basis with the theoretical change for line electrodes (Figure 2b). Calculated boundary potentials, E , eq (11), are indicated in parts (b), shown as covering a range in number of model diameters (1 diam, 2.25-inch) along the abscissas. For these models the boundaries might be imagined as resulting from composite couples in the form of paired line electrodes. The electrical boundary obtained by averaging the ranges resulting from the three sets of calculated data (Figures 9, 10 and 11) is about 3 diameters (based on model diameter).

The data in parts (c) of Figures 9, 10 and 11 were obtained in order to compare potentials, E_p , of the cylindrical couples measured along the A axes, parts (b), with corresponding space potentials of a copper tube having the same external diameter as the cylindrical couples. External cathodic currents were applied to the copper tube equal to the respective values of I_p . The ordinates, ΔE_p , parts (c), are the algebraic differences obtained by subtracting the copper-tube potentials from the potentials of the respective cylindrical couples. It is noteworthy that for distances beyond the effective electrical boundary (14 inches) the effect of the couple becomes relatively constant, therefore indicating the potentials, E_p , parts (b), beyond 14 inches along any axis vary as the function $\log D/a$ (Figure 3). It will also be noted that beyond 14 inches the ordinates, ΔE_p , parts (c), are approximately equal to the couple potentials E_g , parts (a).

3.4. Galvanic Couples With Electrodes Consisting of Cylindrical Segments in Tap Water

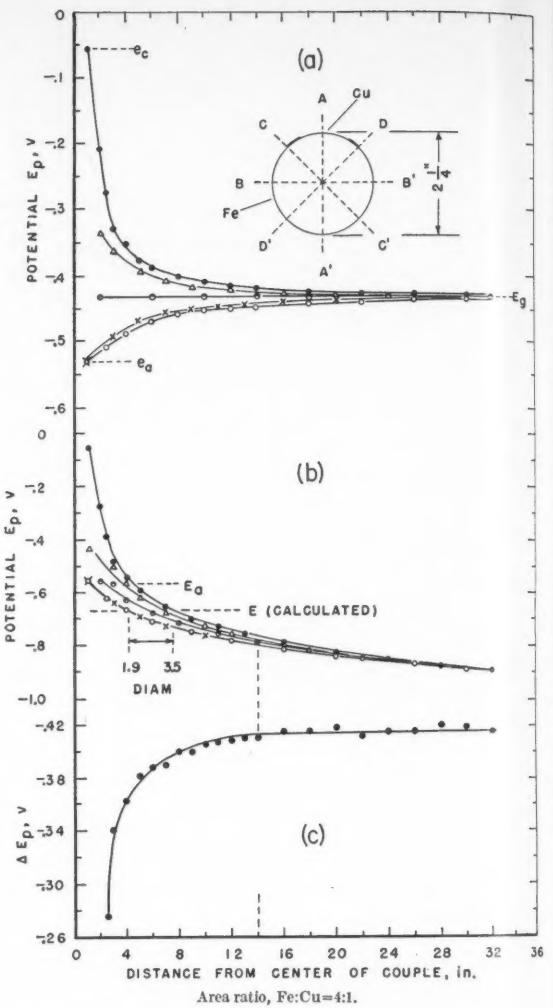
The experiments carried out with the cylindrical couples exposed to N/10 copper sulfate solution were repeated by exposing the same models to Washington, D. C., tap water (resistivity = 5,200 ohm-cm at 60 F) with the idea of observing the effect of polarization, if any, on the electrical boundary. Data for the



(a) $i_0=110 \text{ mA}, I_p=0$; (b) $i_0=0, I_p=120 \text{ mA}$; (c) Same as figure 9 (c).

Figure 10—Cylindrical galvanic couple in a one-tenth normal copper sulfate solution. Symbols are the same as those used in Figure 9.

1:1 couple are shown in Figure 12. That the change in potential, part (a), due to resistance, along the AA' axis agrees fairly well with the theoretical change for line electrodes (Figure 2b) is borne out. For example, at 14 inches the change in potential from the potentials, e_a and e_c , to E_g averages about 92 percent. When external cathodic current, I_p , is applied to the couple the curves converge near the calculated boundary potential, which occurs 5.5 diameters from the center of the couple. The divergence of the curves beyond this point is of no significance and is to be disregarded. The calculated boundary potentials for each of the other two models in tap water, geometrically expressed, occurred at 3.5 diameters, averaging therefore 4.2 diameters for the three models. These electrical boundaries are about the same as the values observed in the copper sulfate solution, in which polarization of the electrodes was relatively insignifi-



(a) $i_0=110 \text{ mA}, I_p=0$; (b) $i_0=0, I_p=146 \text{ mA}$; (c) Same as figure 9 (c).

Figure 11—Cylindrical galvanic couple in a one-tenth normal copper sulfate solution. Symbols are the same as those used in Figure 9.

cant as indicated by comparing the potential changes ($E_c - e_c$) in Figures 9 and 12.

As polarization is of major importance in cathodic protection and the criterion for protection is ordinarily based on a predetermined potential measured between the corroding metal and a reference electrode, the position of the latter must be considered with regard for IR drop included in the measurement. The significance (Figure 12b) of the potential, E , at the electrical boundary as related to the protective potential criterion is discussed in section 4.3.

3.5. Effect of Interference

All experimental data previously discussed were obtained under almost ideal conditions; that is, the tank holding the electrolyte offered little or no interference to the normal flow of current between the anodes and cathodes of the couples. Also, when external current was applied to a vertical cylinder in the center of the tank the current flow was substantially radial, therefore producing nearly equal potential

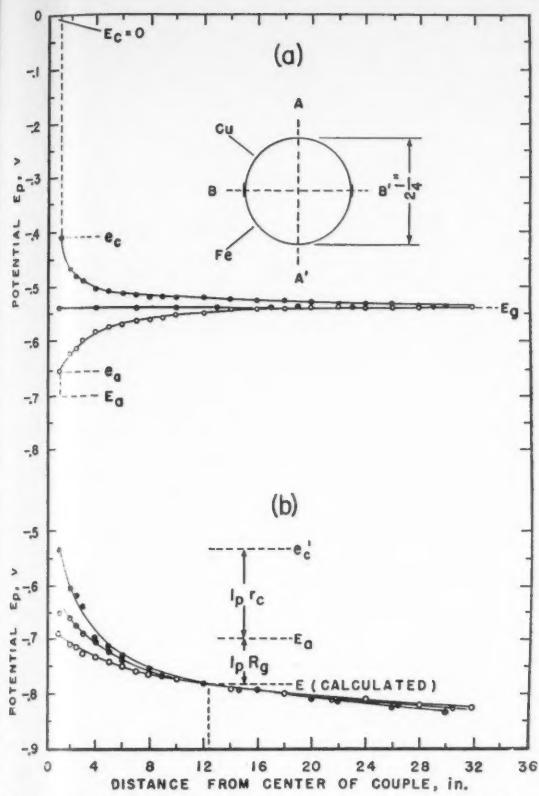


Figure 12—Cylindrical galvanic couple (Figure 9) in Washington, D. C., tap water.

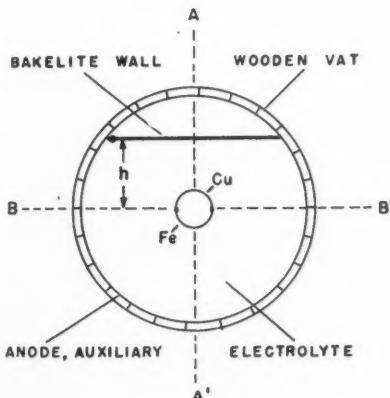


Figure 13—Plan View: Cylindrical galvanic couple (Figure 9) and interference wall (Bakelite) in a one-tenth normal copper sulfate solution.

gradients between any two concentric circles. Practical conditions are generally not ideal, and therefore the experiment illustrated by Figure 9 was repeated with a vertical insulating wall (Figure 13) positioned inside of the vat, thereby shielding any externally applied current normally flowing from that segment of the auxiliary anode. The normal flow of galvanic current is also affected by the insulating wall.

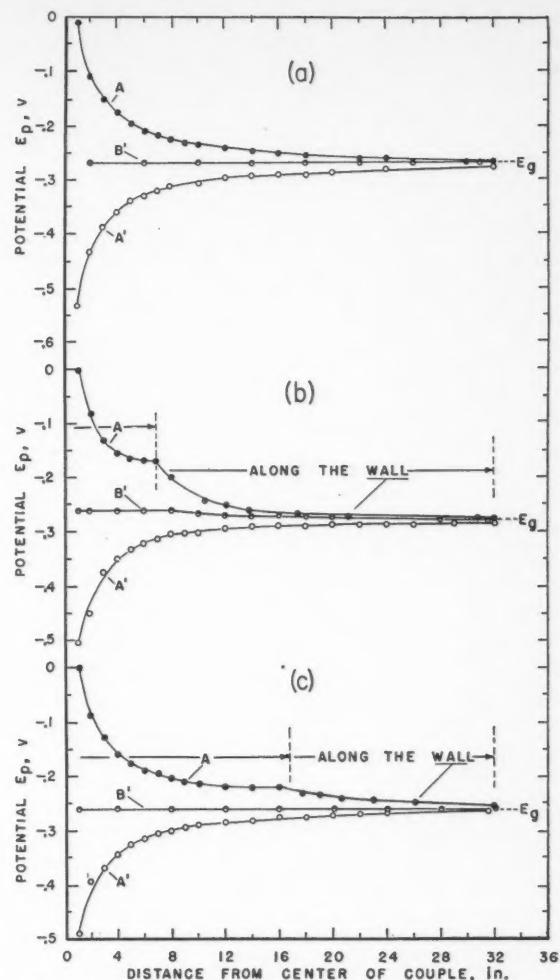
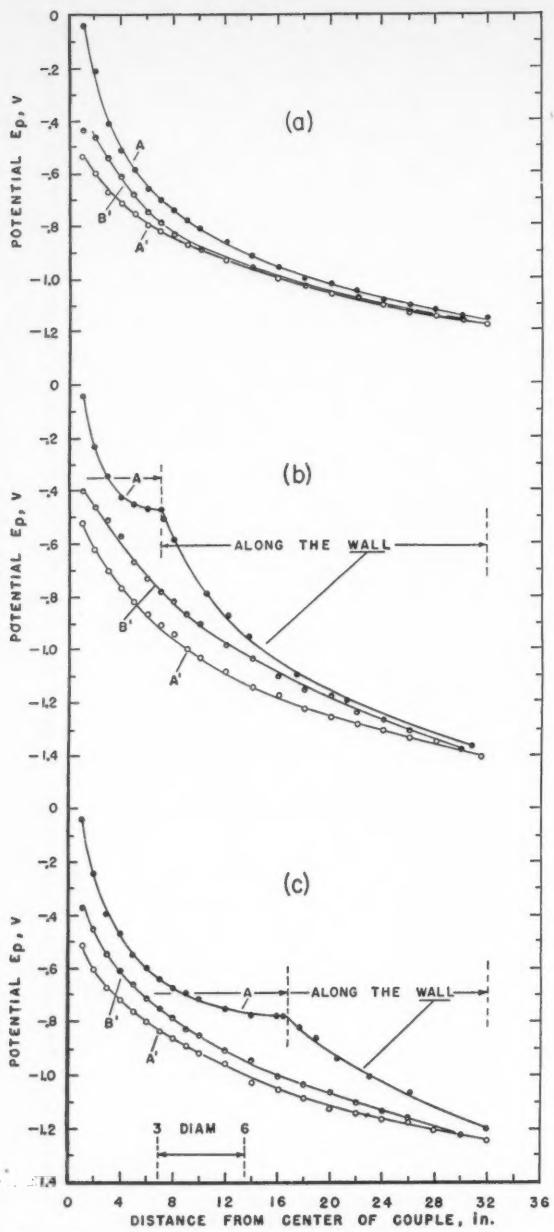


Figure 14—Effect of the interference wall (Figure 13) on the potential lines surrounding the galvanic couple.

Prior to obtaining data on the galvanic couple, external cathodic current was applied to a 2.25-inch-outside-diameter (same as couple diameter) copper pipe positioned vertically in the center of the vat. Potentials measured between the pipe and the insulating wall along the AA' axis and also along the insulating wall were found to fit logarithmic equations used by Scott⁶ and shown by him to apply to the effect of the earth's cover (represented by the dimension, h , Figure 13) on potentials in a plane normal to a pipe line buried parallel to the contour of the earth's surface. Thus, it was established that the Bakelite insulating wall produced interference effects similar to those obtained by Scott, and therefore, the data obtained with the arrangement shown in Figure 13 might be considered as being representative of the effect produced by the earth's surface.

Data on one of the couples, with the wall in two positions, are shown plotted in Figures 14 and 15. Included also for comparison are data, parts (a), applicable when the insulating wall is removed. The breaks in the curves, A, parts (b and c), mark the



(a) No wall, $i_0=0$, $I_p=270$ ma; (b) With wall at $h=6.85$ in., $i_0=0$, $I_p=270$ ma;
(c) With wall at $h=16.75$ in., $i_0=0$, $I_p=270$ ma.

Figure 15—External cathodic current applied to the couple (Figure 14a).

distances, h , along the A axis to the insulating wall, after which the radial distances from the couple center pertain to measurements made along the insulating wall. It will be noted that the wall has the effect of reducing the current density and hence the corresponding IR drops along the A axis, as shown by the relative potentials in parts (a, b and c) of the figures. Without external current (Figure 14), the potential along the BB' axis remains relatively unaffected by the insulating wall, and with external current (Figure 15) the disturbance also seems to be a minimum along the BB' axis, especially in the range from 3 to

6 diameters. That the insulating wall was really effective as a shield, aside from the data fitting appropriate equations, was the fact that when the external current of 270 ma was applied to the couple, the maximum potential variation in the space between the insulating wall and the shielded segment of the auxiliary anode was only 20 mv.

4. Practical Application of the Geometric Relation

4.1. General Considerations

The preceding geometric considerations are applicable in making potential measurements on structures of similar configuration, such as underground horizontal cylindrical tanks and pipelines. In making the application to pipelines it is necessary to assume that most of the corrosion occurring on such lines can be attributed to local action and not to long-line currents. There is good evidence that such is the case. Based on current-flow calculations pertaining to nearly 13 miles of 10-inch pipeline, Scott⁷ concluded that only 6 percent of the accountable total current appeared as long-line current. Scott considered most local action as resulting from current leaving the bottom of the pipe, where the soil is apt to be moist and deficient in oxygen and entering the top of the line, where the adjacent soil tends to be less moist and more accessible to oxygen. It seems that this would be particularly true for large-diameter pipes where there is a considerable difference in soil cover from the top to the bottom of the pipe and where the weight of the pipeline, causing compression of the underlying soil, is also apt to be a factor. Also, further evidence is based on an analysis of other data, obtained by Scott in conjunction with the American Petroleum Institute pipe-coating tests, by Logan, Ewing and Denison,⁸ who found a fair statistical correlation between the corrosion that occurred on bare sections of operating lines and the corrosion of short lengths of small-diameter pipe located nearby in the same trench.

4.2. Location of Corrosive Areas

Scott⁷ discussed the value of pipe-to-soil potentials in disclosing large anodic or cathodic areas along a pipeline right-of-way and also as a way of predicting the general nature and probable extent of corrosion. He also gave a range of pipe-to-soil potentials for iron pipe as related to aeration of the soil, bacteriological activity and relative age of the pipe.

Utilities^{9, 10, 11} measure pipe-to-soil potentials to help in the detection of corrosive areas and in order to decide what protective measures should be taken against soil corrosion.

If, on large-diameter pipelines, corrosion circuits are visualized as existing in the geometrical sense, previously discussed, then a pipe-to-soil potential with the reference electrode placed directly over the line would not represent the corrosion or couple potential because the reference electrode would be within the electrical boundary. The error in the reading, assuming normal soil cover, would depend on the soil resistivity and the size of the pipeline. As the corrosion of ferrous materials in soils seems

to take place under cathodic control,¹² the positioning of the reference electrode as a function of the pipe diameter, for example 4 to 6 diameters, would result in the measured potentials being relatively more significant.

4.3. Cathodic Protection

According to relatively recent reports of the National Association of Corrosion Engineers and the American Gas Association,^{13,14} the pipe-to-soil potential is the chief criterion for evaluating the adequacy of cathodic protection. A reading of these reports leaves one with the impression that the positioning of the reference electrode ought to be done more discriminately. The Corrosion Committee of the AGA revealed that utility companies, applying the -0.85 v (ref. Cu-CuSO₄) protective potential criterion to uncoated pipelines, placed the reference electrode at varying distances from their lines, some placing it directly over the line and others from 5 to 400 feet away. These practices are not conducive to either economical protection for the one extreme or effective protection for the other. The bearing on costs due to such procedures was brought out in a study by Van Nouhuys¹⁵ on 350 miles of 8-inch bare pipeline, wherein it was estimated that in applying the -0.85-v criterion, the cost for cathodic protection with the reference electrode directly over the pipe was more than four times that figured with the electrode positioned at an extreme distance 300 feet away from the line.

The reason for the apparent differences in the current required for the cathodic protection of a given bare pipeline can be illustrated by the laboratory data (Figure 12b), in which the boundary potential, E, might be thought of as representing the generally accepted protective potential (-0.85 v). The pre-assigned potential, E, ordinarily considered necessary for complete protection, can be observed with the reference electrode at different distances from the center of the couple by changing the value of external current, I. For example, to measure the potential, E, inside of the electrical boundary (4 to 6 diameters) requires an increase in external current and outside of the boundary a reduction of current is obviously necessary. The laboratory data might be considered as applying, for example, to the cathodic protection of a long uncoated 12-inch pipeline receiving protective current from remote ground beds. Potentials should be measured at intervals along the line consistent with usual practices, but with the reference electrode placed from 4 to 6 pipe diameters away. Because of the shielding effect of the earth's surface, the measurements should be preferably made in a horizontal plane through the center of the pipeline or at least in a plane somewhat below the earth's surface. Referring to Figure 12, it will be observed that some allowance, depending on the soil resistivity, should be made for I_pR_g, since the protective potential is actually based on E_a. It should be pointed out that in other laboratory experiments, not discussed, the value I_pR_g was found to be negligible for practical purposes when the cylindrical models were exposed to an electrolyte consisting of a solu-

tion of sodium chloride in tap water having a resistivity of 500 ohm-cm or lower.

If, in soils in which I_pR_g cannot be neglected, potentials are measured at the electrical boundary, the potential -0.85 v might be satisfactory as a criterion for adjusting the current initially applied for cathodic protection. The condition for complete protection is expressed by equation (11, that is, E = E_a - I_pR_g, where (Figure 12)

$$E_a = e^1_e - I_p R_g \quad (14)$$

Although bright iron in contact with an air-free alkaline soil can have a potential, E_a, as low as -0.85 v, with respect to a copper-copper sulfate electrode, the average open-circuit potential, E_a, of the anodes on iron or steel field structures, because of the pH and aeration of the adjacent soil, is ordinarily considerably less negative than -0.85 v. If, after having applied a protective current for some time, for example, to a pipeline in a moderately high resistivity soil, the measured potentials, E, had drifted to values more negative than -0.85 v, then, protection would be indicated¹⁶ and I_pR_g probably compensated for.

5. Summary

The theoretical potential pattern in an electrolyte surrounding a pair of coupled line electrodes having different polarities is compared with the potential configuration around an infinitely long cylinder to which uniformly distributed direct current is flowing. By superimposing the coupled line electrodes longitudinally on the diameter of the cylinder, the effective electrical boundary applicable to the combination can be expressed geometrically.

The location of the electrical boundary was confirmed experimentally by comparing potentials measured between model galvanic couples and a reference electrode in a surrounding electrolyte with calculated boundary potentials which were based on the measured electrode surface potentials and electrolytic IR drops.

By using electrical insulating shields, the effects of nonuniformly distributed current on the potential patterns around the model galvanic couples were studied. The position of the reference electrode, under such conditions of interference, which resulted in measured potentials having the most significance was arrived at experimentally. The insulating shields simulated the effect of the ground surface on pipelines.

The electrical relations observed with the laboratory models are believed to apply during the normal corrosion and cathodic protection of bare underground pipelines. Therefore, as a result of these experiments, when making potential measurements, for example, pipe-to-soil, during line-conditioning surveys or when applying the protective potential criterion for cathodic protection, it is recommended that the reference electrode be placed 4 to 6 pipe diameters from the line, at some distance below the earth's surface and preferably in an approximately horizontal position with respect to the pipeline.

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Any discussions of this article not published above will appear in the December, 1955 issue.

DISCUSSIONS ON TECHNICAL ARTICLES ARE SOLICITED

Discussions on technical articles published in *Corrosion* will be accepted for review without invitation. Discussions must be constructive, accompanied by full substantiation of fact in the form of tables, graphs or other representative data and be submitted in three typewritten copies.

Authors of discussions are asked to supply one copy of figures suitable for reproduction and will be sent on request a copy of the NACE Outline for the Preparation and Presentation of Papers.

Discussions will be reviewed by the editor of *Corrosion* and will be sent to the author of the paper discussed for his replies, if any. Publication will be in the Technical Section with full credit to the authors together with replies. Discussions to papers presented at meetings of the association may be submitted in writing at the time of presentation or later by mail to the editorial offices of *Corrosion*, 1061 M & M Bldg., Houston 2, Texas.

Organization and Administration Of a Plant Painting Program*

By W. E. CHANDLER* and C. W. SISLER**

Introduction

BEFORE ENTERING into the discussion of the organization and administration of a plant painting program, basic definitions and philosophy should be established and understood. For simplification the discussion is limited to painting. This represents the portion of the coatings field generally considered by management to be a part of the maintenance function. Here a concise definition of a material is extremely difficult to obtain in terms of composition.

Webster defines paint as a coloring substance, with no reference to the concept of its being a protective coating or a material of engineering. The modern technical dictionaries define paint as "a material of at least partially organic nature which can be used to coat surfaces with films that protect and decorate." The composition of paint is highly important, but the scope of this paper will not permit discussion of formulations; again the discussion will be limited to the partial definition as a material that protects and decorates.

From the plant administrative concept, the primary need for painting is to maintain the basic materials of construction and in this concept painting is completely a maintenance function. Decorative or esthetic painting is necessary but it is usually classified as a construction function rather than a maintenance function and can be obtained at little or no extra cost. This discussion therefore is limited to the maintenance concept.

From a survey of the literature, it is assumed that the total annual cost of industrial painting amounts to about two billion dollars and that the total industrial cost from lack of protection amounts to about five billion dollars.

Plant Painting Program Requirements

The problem facing management is this: To select and apply the combination of materials of construction and paints which yields the best economic combination of installation, maintenance and replacement costs. If this is to be accomplished, there must be developed a well-defined painting program which will both complement and supplement the over-all maintenance program of the plant.

The following elements are believed to be essential to any plant painting program:

1. The design of facilities should include consideration of eliminating the necessity for painting through a selection

Abstract

Management is faced with the problem of selecting the combination of construction materials and paints which will result in the lowest possible maintenance and replacement costs. Developments in the paint field have been very rapid and it is necessary for plant maintenance organizations to re-evaluate painting programs because of this technical advancement.

A sound painting program must include the assignment of sufficient engineering and managerial personnel to the problem. Basic design should be studied in order that unnecessary painting be eliminated and necessary painting simplified. Engineering research studies should be conducted so as to make it possible to determine the materials most suited to the plant environment.

Once an adequate painting system is set up it must be maintained. Maintenance of the system should include periodic inspections and follow-ups; a continuing study of maintenance and replacement costs also should be made. Development of a well-engineered program properly administered normally will lead to more adequate protection with a considerable reduction in maintenance cost.

of materials of construction, the reduction of exposure to corrosive atmospheres, and the selection of structural shapes and elements which favor easy paint maintenance.

2. Engineering and management talent commensurate with the problem must be assigned to the maintenance painting and be allowed to manage the function.
3. Painting must be viewed as a system made up of various elements consisting of:
 - a. Surface preparation.
 - b. Properly selected materials best suited for the environment.
 - c. Application techniques which ensure that the materials are used in the manner which produces the most economical protection.
4. Once an adequate maintenance painting system is applied to a facility, the painting system itself must be maintained and not be permitted to fail.
5. No sound program is complete without well-engineered and adequately administered day-to-day long-range scheduling.
6. Inspections of work in progress, as well as inspections of systems already applied, are of primary importance.

Experiences in setting up such a program within a large integrated chemical plant will help define the approach and can be used for predicting future results.

The program was started less than two years ago. At that time the plant was spending from \$300,000 to \$400,000 per year on maintenance painting. The greatest part of the work was performed by a group of plant painters under the direction of two non-technical foremen. The only engineering supervision provided was on a side line basis. Paint testing had been undertaken over a period of years but was never engineered sufficiently to obtain consistent

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** Plant Engineer, Monsanto Chemical Company, St. Louis, Mo.
*** Staff Superintendent, Monsanto Chemical Company, St. Louis, Missouri.

data. Most of the testing was conducted by actual field tests with noticeable interference to the plant painting effort.

The maintenance department supervised the work of the plant painters and contractors but the manufacturing department supervisors decided when and under what conditions the painting was to be done. The greatest part of the painting was done on a small job basis rather than on a departmental basis.

Surface preparation was recognized as part of a paint job but it was not given proper emphasis. Minimum film thickness, compatibility of materials and classification of environments were not given any real consideration. The application of a primer and one finish coat was considered standard; the average service life of the systems was two years.

This non-technical approach did not control surface corrosion in the plant. Sufficient effort was expended to ensure good plant appearance, but only the less corrosive areas were fairly well protected while the more corrosive areas were inadequately protected.

The painters were widely dispersed in the plant, making adequate supervision almost impossible. A large portion of the painters' time was spent traveling from one small job to another and in changing from one type of paint to another. Training was projected toward average attainment and morale was not high.

The non-technical approach did not consider the economic potential of design as a weapon of corrosion attack and it failed to recognize the value of using economic and technical data to determine the necessity for painting.

Application of Engineering Management

The first step in the application of engineering management to the problem was to place the direction of the entire painting program in the charge of an engineer who devoted his full time to the project. This engineer handled the staff and liaison functions of the assignment as well as the direct supervision of the paint force. Evaluation of materials, application techniques, scheduling, training, and the overall economics of the problem were made his direct responsibility.

One of the initial accomplishments was the reorganization of scheduling procedures; the minor-repair concept of maintenance was discouraged, and scheduling of projects of departmental scope was projected on the basis of total man-hours available during the year. Approval of painting projects as a year's work was granted by top management with a resulting improvement in efficiency of operation. Coordination of major projects with production requirements and vacation schedules was effected. Adverse weather conditions no longer created a lag in effort; it was possible to integrate both inside and outside work on a flexible basis. An improvement in employee morale was noticeable as the changes were put into effect.

Complete coverage of the plant was scheduled to be accomplished in five years. The five year schedule provided for a gradual decrease in departmental

painting with a corresponding increase in inspection and spot repair of departments which had been completed. Estimated annual budgets were prepared on this basis and submitted for long-range approval.

Design engineers were requested to make a study of materials of construction selection and processing which might reduce the scope of painting problems in the future. The possibility of introducing more extensive use of plastics and alloy-metals in order to minimize painting requirements was considered by this group. Design features which had made the maintenance of painting surfaces difficult were minimized. Tubular columns and surfaces relatively free from obstructions were employed in the construction of one large laboratory building, and the best features of such construction were considered for further implementation. Design specifications were adjusted to suit field requirements for painting and corrosion control.

A study of surface preparation was undertaken—it consisted essentially of obtaining a surface which was clean and free from all loosely adherent foreign matter. This clean surface when coated would not alter as long as the coating remained intact. Breaks, fissures or holidays in the film permitted the surface to revert to its originally contaminated condition.

The nature of plant processes prohibited the employment of sandblasting in many plant areas; the use of hand scrapers, single and triple scalers, power chisels and brushes, hand wire brushes and sandpaper were adopted as a standard method of surface preparation in these areas. However, sandblasting was employed wherever possible. Prior to most major painting projects, the services of an outside contractor who specialized in cleaning with high pressure water and steam solvents and detergents were used to advantage.

Evaluation of Coatings

An impartial evaluation of all commercially available generic types of coatings was made in cooperation with an outstanding consultant in the field of corrosion prevention. Coatings were exposed in each of ten exposure areas in the plant. Unique panels and accelerated methods employed in evaluating the results of coatings exposed provided accurate qualitative data for selecting the materials most suitable for each environment. One generic type of paint used widely in the plant for a number of years was proved incompatible with exposure conditions (it failed rapidly in all but the most mild areas.) Out of 13 generic types of coatings tested only four showed no damage in the more severe areas and only seven were considered of value in the plant.

Implementation of the program was begun in earnest after evaluation techniques proved the validity of surface preparation and materials selection procedures. Proper application of the selected materials was the next consideration.

It was determined that the minimum dry film thickness for a system should be five mils. It was also determined that a standard system should consist of one prime and two finish coats as a minimum with additional finish coats to be applied if necessary to

attain the five mil film thickness. Inspection with a magnetic thickness gage insures a minimum of five mils dry film thickness during application. It was decided that the prime coat should be brushed whenever practical, and that finish coats should be applied with brush, roller, conventional or hot spray according to exposure conditions and to production department restrictions. It is of interest to note that the application of paints to large plane surfaces by conventional roller requires approximately one-third the labor required by brush application.

With the introduction of new paint systems and application techniques, it was necessary to provide for additional training of the painters. As each new paint was selected, each painter was told of the reasons for its selection, and instructed in what to expect in coverage properties, methods of mixing and thinning, and the most effective methods of application. The painters were receptive to new ideas and interest has continued. Requests for additional information concerning evaluation and inspection techniques and new methods of application have been received from individuals and from the group. Morale of the painters increased as training progressed.

Inspection System

Next, a rigid system of inspection and spot repair was established. When a department was painted, a record was prepared showing the number of coats applied, the nature and quantities of primer and intermediate coats, the method of surface preparation, labor man-hours and unit costs. The record form was designed so that three months after painting was completed the form could be posted by the maintenance clerk for the primary inspection. A competent salaried inspector handled the procedure. Inspection was as thorough and meticulous as possible.

During the process of inspection, a mechanical device was used which detected pinholes, voids, breaks and bare spots in the film. This device provided an accurate inspection instrument for checking the continuity of the coating. Breaks in film continuity were marked and spot-repairs of the area were made at once. Cost and other pertinent data for each inspection were recorded and the record was returned to the file.

As a basic concept of adequate maintenance, it is anticipated that inspection and spot-repair will be required at intervals of eighteen months throughout the life of a system. This assumption will be retained until more detailed knowledge of performance is acquired from actual field experience. When the rate of deterioration of film in a given area is determined, frequency of inspection can be established and inspection intervals can be varied to suit the severity of the individual exposure areas. It is anticipated that one complete cover coat will be necessary after the sixth year of service to restore film thickness lost because of chalking or abrasion or by washing for housekeeping purposes.

Conclusions

Results of the program cannot be considered positive as yet. As has been stated above, the program

was started less than two years ago. Reorganization of methods and evaluation of materials and techniques utilized the first year. The one year of actual program implementation has been too short a time in which to realize the real benefits which are possible. However, one accomplishment already realized is the reduction of the cost of paint application from an estimated 76 cents per square foot to 44 cents per square foot. Another is the protection to metal surfaces from the system now being applied. And a third accomplishment is the improved coordination between other maintenance activities in well-painted departments.

Anticipated results of the program have been analyzed and realistic comparison with former methods is possible. In former years, paint systems were applied which had a service life of two years. Little or no maintenance of the systems was attempted after the service life was expended. The cost of paint maintenance per square foot of surface per year ranged between 15 and 20 cents. The cost of application, inspection, spot-repair and periodic cover coats of properly selected and applied long-life systems is expected to be 10 cents or less per square foot of surface per year. This anticipation of increased plant protection at a cost reduction of 25 to 30 percent is adequate justification for the application of engineering management to the painting problem.

DISCUSSION

Questions by Edward G. Brink, American Viscose Corporation, Marcus Hook, Pa.

1. What is your method of correlating the coating evaluation program with the actual field application conditions? For example, if tests are conducted on sandblasted or wire brushed steel panels, what assurance is there that a coating system which proves satisfactory under these circumstances will provide the necessary protection if it must be applied over an old coating on plant equipment or structures?
2. What methods of control are employed in the field to assure good workmanship with respect to both surface preparation and the coatings applied? In other words, how do you determine if the workmen are cleaning the surfaces in conformance with the specifications and that the desired film thickness and freedom from holidays and pinholing have been obtained?
3. Are any extra precautions taken to assure proper protection at weak points, such as edges, welds, etc.; for instance, do you double coat edges?

Replies by C. W. Sisler:

1. Inspection is the key to correlation between evaluation and application. Our inspectors are preparing a case history for every department and area in the plant. These case histories will include the following items and are filed in the engineering department for reference:

- a. Primary and secondary chemical exposures.
- b. Exposure classification in degree of severity.

- c. The actual area in square feet of surfaces to be protected against corrosion.
- d. The corrosion rate in IPY.
- e. Rate and extent of average spillage.
- f. Method and rate of film deterioration.
- g. Mechanical or production activities which affect surface preparation and application techniques.
- h. Type, cost, extent and service life of coatings applied in former years.
- i. Type of coating and surface preparation recommended for area by evaluation program.
- j. The percentage of total area in which existing paint film is intact and tightly adherent.

When the engineering department knows the paint film in a given area is 70 percent intact and tightly adherent, recommendations for painting are made accordingly. Follow-up procedure involves washing the area with detergent and high pressure water, rinsing to a neutral pH, preparing the surface of exposed areas with hand or power tools, featheredging tightly adherent film and spot-priming the deteriorated areas. Other steps include application of a tie-coat compatible with both the existing paint and the coating recommended for the area by evaluation facts, and application of sufficient cover coats to guarantee a minimum dry film thickness of five mils.

2. Again, inspection is the key to success. Rigid specifications are prepared for all phases of painting

work and employ salaried inspectors to enforce them. Inspectors are constantly on the job and have full authority to stop work until specifications are complied with. Surface preparation is checked constantly while in progress; each coat is inspected with implements at random with special precautions being taken to assure high build at edges, welds and prominences.

3. Our painters are trained to flow paint toward edges and welds and to use a wet brush. It has been our experience that edges, welds and prominences are the areas of almost total paint failure on projects being painted; special consideration is given to prevent recurrence of the condition. Double coating or application of fibre glass reinforcement is often employed.

Question by Mack Abraham, Cities Service Refining Corporation, Lake Charles, La.

What procedure has been set up for painting a unit or piece of equipment after it has been shut down and dismantled for repairs?

Reply by C. W. Sisler:

Excellent communication between shop, area and painter foremen result in fast, efficient work. When area workmen dismantle equipment and send it to the shops for repairs, the paint inspector is notified automatically. He inspects the equipment, makes recommendations for cleaning, surface preparation and painting and reports to the painter foreman who checks with the shop foreman on scheduling of work. A shop painter is available for this type of work.

Any discussions of this article not published above will appear in the December, 1955 issue.

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Basic Essentials for the Reduction Of Atmospheric Corrosion*

By FRANK RADECKE

Introduction

DISCUSSION at technical meetings, mail, and phone inquiries indicate that industry in general is becoming acutely aware of atmospheric corrosion costs. The costs are measured in terms of equipment replacement and protection. Replacements obviously are less frequent or unnecessary if the protection is adequate. Modern industry, working with corrosive materials and products that were only laboratory wonders a few years ago, is constantly beset by new problems of atmospheric corrosion.

Protective coatings applied to steel or other surfaces long have been recognized as the most economical means of reducing the effects of atmospheric corrosion. It appears that engineering in the field of paints and their application has not kept pace with other industrial developments. Plant painting has been regarded as a necessary evil that is repetitive in nature. However, higher labor costs and increased corrosion rates have drawn management's attention to the fact that protection is growing more expensive. Short coating life, high unit cost, and unsatisfactory protection are common experiences.

There are ways and means to be adopted to the reduction of atmospheric corrosion and related costs. This paper outlines an adaptable procedure based on the Shell Oil Company program initiated six years ago to improve exterior coating protection and durability. The project was developed in four phases, as follows:

1. Program
2. Organization
3. Material
4. Application

In conclusion, cost data based on Shell findings are evaluated; they indicate that savings on the order of 50 percent in application costs can be achieved. The unit cost per year of coating life, which is the true cost measure, yields more favorable results.

Program

There is a great deal of good technical literature available on all phases of painting in publications issued by the Steel Structures Painting Council and others.¹ There are also private consultants, federal agencies, and technical staffs in modern paint companies whom the engineer may consult regarding surface protection in his plant.

FRANK RADECKE is a veteran petroleum engineer whose last 21 years have been spent with the Shell Oil Company. A senior engineer at the company's Wood River, Illinois, refinery since 1943, he was assigned recently to the New York office to head engineering standards development. He is also chairman of the manufacturing department's atmospheric corrosion committee which is concerned primarily with corrosion mitigation. Mr. Radecke attended Washington University of St. Louis and the Illinois Institute of Technology.



Abstract

A four phase plan used by a refinery to reduce atmospheric corrosion through the improvement of exterior coating protection is described. Included is a discussion of factors to be considered in setting up a maintenance painting program.

It was found that paint engineers will be concerned primarily with four matters: Selection of paint with respect to environmental severity, surface preparation, dry film thickness, and number of coats to be applied. It was found that the best combination of these factors must be determined by the engineer in order to ensure that the plant has adequate protection within the limits of economic practicability.

A plant specification standard prepared by an oil company is given.

After acquiring the proper background, the engineer should prepare a manual or handbook on painting to fit the needs of his particular plant environments. The manual will be used for the guidance of technical and craft personnel in all steps of surface preparation and paint application. In other words, a consistent policy should be established for all maintenance and construction painting.

The manual should include specifications for different types of surface preparation, paint systems, prime and finish materials, color systems, dry-film thicknesses, etc. Inasmuch as an educational program is indirectly but necessarily contained in a policy manual, sections devoted to paint failures due to atmospheric corrosion, pigments and vehicles, paint manufacture, and testing are essential also. Small concerns with limited atmospheric corrosion problems may find it more practical to adapt existing publications to their problems. In any event an outline of procedure and policy for permanent guidance is the essential starting point.

Organization

A successful maintenance painting program in an

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industrial plant requires the direction of an engineer (full or part time, depending on the size of the plant.) The paint engineer is responsible for interpretation of the paint manual or other authoritative literature on the subject. He should handle the development of paint systems of the right materials for his particular environments, initiate test applications and procurement specifications.

Achieving coatings of good quality and durability is largely a matter of selling an idea. Once management has approved the outlay of time and expense for a coordinated program, the engineer must accomplish results through the paint craft foreman or contractor. It therefore becomes necessary to work closely with these people to develop in the craftsmen new concepts of painting. The old practice of obtaining the maximum number of square feet coverage per gallon must be changed to one of getting maximum thickness per coat regardless of paint consumption rates. It is difficult to teach the professional house painter new industrial painting concepts, especially spray painting. It is essential to obtain intelligent craftsmen who will be receptive to training on how to spray uniform coatings of the desired film thickness.

The paint engineer also must establish coating and cost records which will show readily the necessary data. These records will indicate which paint systems are enduring well and the probable reasons for early failures of others. Cost data are important as a measure of progress.

Inspection of all coatings and surface preparation is essential. The engineer may do the work or, in the case of extensive paint programs, an experienced painter craftsman may be upgraded. The inspector will cover the activities of both maintenance and contractor's forces. His duties will include examination and approval of all surface preparation, visual inspection and measurement of dry paint films, the use of additives in paint for various purposes, and the accumulation of data for cost and material records. The craftsman inspector should be educated thoroughly in the aims of the program in order that better coatings may be obtained. He also should have a knowledge of the properties of various paints used, to the extent that he may make spraying corrections at the start of an application instead of facing the necessity of doing an unsatisfactory coating over again. Inspection of all phases of paint work, and checking to see that engineering specifications are adhered to, definitely will prove to be most profitable.

Materials

Material selection requires technical assistance and judgment on the part of the engineer. Considering the protection of metal surfaces, material selection will be based on quality of surface preparation, environmental severity, and favorable costs. Therefore, a durable coating system that can be applied readily in sufficient film thickness at reasonable cost is the objective.

Before proceeding with the subject of material selection, a few basic factors should be outlined for engineering guidance:

- a) Sandblasting to bare metal on all steel surfaces will pay out. Properly cleaned and primed surfaces will not require renewal of prime coats during the life of the substrate in most atmospheric exposures. The grade of sandblasting or cleaning will be governed by the severity of the environment.
- b) Sandblasted or acid-cleaned surfaces must be painted with a prime coat on the same day that cleaning is performed. Surfaces exposed to water in the interval between cleaning and priming must be recleaned.
- c) Multiple coat systems (preferably two prime and two finish coats) appear to give the best results. Theoretically, the double coating of each type ensures full coverage in thin areas and eliminates pin holes and voids.
- d) The coverage rate in square feet per gallon is secondary to dry film thickness per coat. A minimum of one mil per coat for all but the wash primers is the generally accepted minimum. The minimum total dry film thickness for any paint system should not be less than five mils to realize the full potential of the protective coating investment.
- e) Primers should contain sufficient inhibitive pigments to achieve adequate chemical reaction with the steel surface. Inert pigments do not have rust inhibitive properties.

Paint Selection

There are a great number of corrosion-resistant paints on the market, and it is difficult to make selections other than by trial and error experience. The paint engineer therefore would do best to take advantage of exploration in the paint material field concluded by others. Data prepared by federal agencies, the Army Corps of Engineers, and the Bureau of Ships is available to industry. The Steel Structures Painting Council data is excellent. Private consultants and experts in the basic paint materials field are available to the engineer for assistance in quickly starting a program with proven materials.

Preparation of specification formulas for paint is another approach to the problem of material selection. However, company paint specifications will not be profitable unless consumption rates are high, and unless there is an engineering organization to administer the program and to establish analytical controls for delivered materials.

In general, paints made with modified alkyd and phenolic resin vehicles have been most commonly used for exterior industrial protection. The chlorinated rubber and vinyl coatings are being applied in the more severe exposures. The more recently developed Epon resin-based paints are most attractive for the mitigation of atmospheric corrosion. The coating resistance in industrial environments is excellent and the film build per coat is high. The economics of Epon coatings, ester or catalyzed types, are attractive for general plant painting in mild or severe environments.

Specification 19-1.23 Type I-Tank White-Alkyd Varnish Paint

Shell Oil Company, New York, Material and Equipment Standards Protective Coatings

1. General Requirements

a. *Condition in Container:* The paint shall be well ground, shall show no skinning in a freshly opened full can nor settle badly, liver, gel, or cake in the container. It shall be capable of being readily broken up with a paddle to a smooth uniform paint.

b. *Working Properties and Appearance:* The paint shall have good brushing and spraying properties, shall work easily, possess good leveling, and shall dry to a uniform, smooth gloss finish without streaking, running, wrinkling, or sagging.

2. Composition*a. Pigment:*

The proportions of the various pigments on a percentage by weight basis shall be as follows:

Percent By Weight

	Min.	Max.
Titanium Dioxide (Rutile)	64	66
Zinc Oxide	8	9
Magnesium Silicate	—	28

The extracted pigment on analysis shall conform to the following quantitative requirements:

Percent By Weight

	Min.	Max.
Titanium Dioxide	62	—
Zinc Oxide	7	9
Silicates	—	25

b. Vehicle.

The vehicle shall be composed of a pure, oxidizing, long drying soya oil glycerol phthalic anhydride solution, containing 25 percent phthalic anhydride (70 percent solids), the necessary driers, and thinner. The volatile portion of the vehicle shall be free from benzene and chlorinated solvents. The component ingredients shall be free from rosin and rosin derivatives. Only cobalt and calcium driers shall be used. Lead containing compounds are not permitted. The varnish shall be clear, transparent, homogeneous, and shall not form a skin within 48 hours when stored in a $\frac{3}{4}$ -filled, tightly closed container. The materials shall be used in the following proportions on a percentage by weight basis:

Percent By Weight

	Min.	Max.
Alkyd Resin Solutions	75	77
Mineral Spirits	22	24
6 Percent Cobalt Drier	0.44	0.46
5 Percent Calcium Drier	0.53	0.55

c. Varnish Properties:

The varnish processed in 2b shall have the following properties when tested by methods prescribed in 4.

Min. Max.

Nonvolatile content, % by wt.	52	—
Volatile content, % by wt.	—	48
Phthalic anhydride content of nonvolatile, % by wt.	23	—
Viscosity (G-H), 77 F.	C	F
Drying time (70-80 F.; 60-70% relative humidity), hrs.	Set to touch	1 3
Dry through	—	18
*Acid resistance, hrs.	24	—
*Gasoline resistance, hrs.	24	—
Gas and draft test	Shall pass test	
Flash point	30 C	—
Rosin and rosin derivatives	None	

d. Paint: The finished paint shall conform to the following compositional and property values:

Min. Max.

Pigment, % by wt.	34	—
Vehicle, % by wt.	—	66
Vehicle solids, % by wt.	52	—
Phthalic anhydride content of nonvolatile vehicle, % by wt.	23	—
Uncombined water based on total paint, % by wt.	—	0.5
Coarse particles and skins Total retained on 325 mesh sieve based on paint, % by wt.	—	1
Krebs-Stormer shearing rate 200 rpm., Grams	155	175
Equivalent K. U.	73	77
Drying time, hrs. set to touch	1	3
Dry through	—	18
Fineness of grind	3	—
Weight per gallon	10.2	10.3

REDUCTION OF ATMOSPHERIC CORROSION

Prime Coats

Regardless of how material selection is made, certain basic types of coatings are needed for steel surfaces. It is necessary to keep in mind that labor costs dictate spray application wherever possible. Therefore, the first prime coat should have an inhibitive pigment in a surface wetting vehicle that is fortified with resin solids. Such a primer will flow well on steel surfaces when sprayed and will be reasonably durable. The second prime coat also should be an inhibitive type, with greater resin content so that it will produce a hard film. Finish coatings should contain inert pigments that will not react with the intended environment.

Vehicles for finish coats should be made of the best resins and oils available of the type selected. The vehicle is in reality a binder. The finest pigments can be blended with a binder not suited to a particular industrial environment, and early failure of the dry film can be expected. The point is that a suitable paint must have well-balanced physical and chemical properties for the intended environment. The Shell Oil Company white tank paint Specification 19-1.23, Type I is a typical formula for an exterior finish.

Application

One of the first steps in this phase of atmospheric-corrosion mitigation is a study of surface preparation. Hand cleaning tools should be supplemented with pads of heavy grit papers which improve surfaces for painting and reduce cleaning time. Power cleaning tools are a third choice. Because it cleans more satisfactorily, sandblasting is the preferred method of surface preparation. The degree of cleaning on blasted surfaces is important because of the wide variation in costs. Commercial blasting, or a slightly clouded finish, is the desired standard for most environments. Metal white blasting finishes cost virtually twice as much as commercial work.

The Ottawa sawing type of blasting sands are among the best available. They are highly graded, clean products. The grades that substantially

pass through US standard 40-mesh sieves are preferred for most blasting. The cost is approximately \$5 per ton in bulk and \$10 per ton in bags. Nevertheless, bags are preferred where mechanical handling facilities exist. Bulk handling costs substantially exceed the \$5 differential between the two types of shipment.

A blasting trailer-mounted machine with two outlets for twin operating nozzles and one helper is most efficient. A 500 cubic foot per minute compressor with a discharge pressure of 100 to 110 psi should be coupled to the blaster. Dual blasting equipment will eliminate one helper, thereby effecting a 25 percent reduction in labor.

Thin and uneven spray painting is the next difficulty to overcome. The first step is to instruct the supervisors and craftsmen in protective coating objectives. Condensed texts can be prepared for the information of the painter-craftsmen. Portions of spray painting films, issued by spray equipment manufacturers, also will be helpful. This should stimulate better performance from the craftsmen in the field. The major points to emphasize are spraying with low pressures and operating the spray guns close to the surfaces to be coated with the correct gun adjustment for good pattern. Addition of extra paint to edges, crevices, and irregular areas with the guns held at right angles to the surfaces being sprayed also should be emphasized. Because of surface preparation cost, the economics of an exterior coating system dictate minimum spreading rates or the maximum possible wet-film application without sags or runs.

Portable Paint Pump

The greatest single labor-saving device developed in recent years for spray painting probably is the portable paint pump. The reciprocating type is preferred because it operates only when a spray gun is open. Medium-sized units are capable of a maximum discharge pressure of 550 psi on an input of 100 psi of air to the drive cylinder.

The pumps can be throttled down to normal painting pressures, 20 to 60 psi discharge, by means of diaphragm control on the inlet air to the driver. These pumps can best be described as being similar to those used in service stations to grease automobiles. Attached to the rims of open barrels used for paint reservoirs, the pump foot valve is immersed in paint. Paint supply can be replenished at any time during spraying—without a shutdown—because the reservoir is not under pressure.

For large projects the pump and barrel reservoirs should be placed at a convenient roadside spot or in a paint trailer located at roadside. Paint deliveries from warehouse stock then can be brought alongside with a minimum of handling. The reservoir is filled, the pump is set at the desired discharge pressure, and the hose is pulled off a reel with a paint supply being fed from the pump through the reel hub shaft to the hose. The hose lines and spray guns are the only equipment to go into the work area. Four spray guns can operate successfully from one pump at distances up to 1200 feet and at 50-foot elevations or as high as 150 feet in the immediate vicinity of the

pump. The $\frac{3}{4}$ -inch pump discharge hoses can be reduced to $\frac{3}{8}$ -inch hoses by means of Y connections for the last 100 feet to permit multiple-gun operation.

Whenever painting operations are to continue the next day, the hose lines may be left stretched out and under pressure overnight. The guns are then placed in a pail of distillate to prevent the material from hardening on gun tips. This practice will save daily equipment cleanup time. When changing paint in the reservoir, or upon job completion, equipment cleanup may be accomplished by placing the pump in a container of suitable solvent and pumping through the hose lines back into the same container.

Dry Film Gauge

An essential quality control tool is the dry film gauge. The permanent magnet type in pocket size is most practical for widespread field use. The practice of constant inspection and the use of the film gauge will result in fairly uniform coatings with the desired minimum thickness of one mil per coat. The average film thickness for a good four-coat system will be approximately 5.5 mils and should not be less than 5 mils. The desirability of adequate film thickness cannot be overemphasized.

Warm, bare equipment surfaces will have low external corrosion rates and therefore will require less protection, so a three-coat system normally will suffice. Insulated equipment and piping should be primed with two coats under the insulation if the operating temperature is less than 220 F. Surfaces above this temperature under insulation should require no coatings. Corrosion occurs on insulated surfaces at temperatures up to approximately 220 F. Two coats of inhibitive primer before insulating will check the attack.

The objective is to obtain the maximum film thickness compatible with good economics and severity of environment. Film thickness is proving to have a direct relationship to surface protection and coating longevity. In any event, paint systems cannot be preconceived for all surfaces in industry. The paint engineer must exercise judgment in the recommendation of coating systems or special materials whenever corrosion indicates a need.

Evaluation

The foregoing program is the one that was adapted by the Shell Oil Company more than six years ago. It is adaptable to any plant, large or small. Discussion of economic factors is based on actual experience in one of the company's refineries, although favorable results have been gained in all of the plants.

The problems of atmospheric corrosion are far from solved, but favorable results from the current program are becoming apparent. An outline of direct costs per unit of large storage tank surfaces in one of the refineries will best illustrate progress.

In 1948 an average of \$24 per square (100 square feet) was expended to sandblast and to apply two coats of poor paint on new steel. The labor and material ratio was 4:1, and coating life was 2.5 years. Dry-film thickness was not known but, at best, it

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could not have exceeded two mils. The mean cost per square per year of film life was \$9.60. In most cases the single coat of inert primer was in a generally failed condition and required replacement.

Since the program was inaugurated in 1948, the painter has had an hourly rate increase of more than 24 percent. The current average expenditure is \$10 per square to sandblast and to apply four coats of paint on new steel. The labor and material ratio is approximately 1:1 and dry-film thickness is from 5.5 mils to 6.0 mils. Subsequent coating measurements on many surfaces indicate a minimum life of seven years. On this basis the cost per square per year will be \$1.43.

It is anticipated that the red lead prime coats will not require renewal for the life of the tanks, provided that new weather coats are applied when needed. Spot priming and two finish coats currently are being applied for a maximum of \$6 per square, which should

yield another seven years of weather-coating life. On completion of the second paint cycle (14 years' total) the unit cost per year of life would be \$1.14.

Conclusion

In conclusion it is pointed out that all of the company's coatings were not entirely faultless. Coating repairs have been made on a spot basis in a few instances. However, proper material selection, trained craftsmen, good surface preparation, and application of sufficient film thickness—coupled with aggressive inspection and supervision—are yielding protection against atmospheric corrosion at substantially lower cost. The best measure of progress is the extent of protection afforded at low unit cost per year of coating life.

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*Any discussions of this article not published above
will appear in the December, 1955 issue.*

A REVIEW

Microbiological Corrosion of Iron and Steel*

By DAVID M. UPDEGRAFF

Introduction

THE corrosion of iron and steel is an electrochemical process. It is now clear, however, that microorganisms often exert effects which increase or decrease corrosion rates and which may be an important cause of corrosion under certain conditions.

In order for microorganisms to promote corrosion, the environment must be suitable for their growth and multiplication. The essentials for microbial growth are moisture, a suitable pH, certain essential minerals (including phosphorous, potassium, nitrogen, sulfur and iron), a carbon source (organic matter or carbon dioxide), and an energy source (sunlight, organic matter, or an oxidizable inorganic substance). All these essentials ordinarily are present when iron or steel comes in contact with any natural water, such as sea water, river water, lake water, or moist soil. Thus it is hardly surprising that microbiological corrosion is a common and wide-spread process responsible for great economic loss.

Historical Information

As early as 1910, Gaines¹ proposed the theory that bacteria act as corrosive agents in the soil, but his paper attracted little interest. In 1934 von Wolzogen Kühr² proposed a theory of anaerobic bacterial corrosion which generally is accepted today. Since that time, much excellent work has been done by the Chemical Research Laboratory at Teddington, England (Butlin, Vernon, and Whiskin³), by Hadley,⁴ by Starkey and Wight,⁵ and by von Wolzogen Kühr and Van der Vlugt.⁶ It has been only during the last few years, however, that corrosion engineers have come to recognize the importance of microorganisms in the corrosion of iron and steel.

Mechanism of Corrosion

Electrochemical Factors

At the risk of presenting obviously elementary material, a brief summary of the electrochemical processes of corrosion will be given. This is desirable because some of the more important ways in which microorganisms affect corrosion are through the indirect influences they have on electrode potentials and concentration cells.

Processes used in the manufacture of articles of iron or steel introduce a degree of physical and chemical heterogeneity. Thus, when the metal is placed in contact with water, certain areas develop different potentials from other areas. At the more electro-negative anodic areas, iron goes into solution as ferrous ions, thus liberating electrons; ferrous ions

DAVID M. UPDEGRAFF is engaged in research microbiology work for the Minnesota Mining and Manufacturing Company, Saint Paul, Minnesota. From January, 1948 to July, 1955 he did work in petroleum microbiology research for the Magnolia Petroleum Company, Dallas, Texas. He received a BA degree in bacteriology from the University of California at Los Angeles, and a PhD degree in microbiology from the Scripps Institution of Oceanography, La Jolla, California.



Abstract

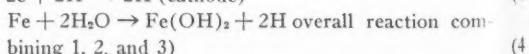
A critical review of the literature on microbiological factors involved in the corrosion of iron and steel is presented. A brief account of the historical aspects of the subject is given along with a discussion of the mechanisms by which microorganisms affect corrosion, a description of some typical examples of microbiological corrosion and a discussion of methods used to prevent microbiological corrosion.

It was found that while microorganisms do not corrode iron or steel, they often produce major physical and chemical changes in the environment. These changes may influence the electrochemical processes responsible for corrosion and thus markedly accelerate (or under different conditions decelerate) the corrosion rate.

It was found that microorganisms sometimes coat metal surfaces, influence galvanic cells, affect pH or acidity, affect redox potentials, catalyze chemical reactions which influence corrosion, and change oxygen tension. A description of how anaerobic bacterial corrosion is carried out by sulfate-reducing bacteria is given.

Methods of alleviating microbiological corrosion are found to include cathodic protection, protective coatings, germicide treatment of water, and alkali treatment.

then react with water to form ferrous hydroxide and hydrogen ions. At the more electropositive cathodic areas the electrons combine with the hydrogen ions to form cathodic (atomic) hydrogen. The cathodic hydrogen, as it accumulates, forms gaseous molecular hydrogen. These reactions are illustrated in the equations below:



According to the law of mass action, any decrease in the concentration of hydrogen or ferrous hydroxide will accelerate the corrosion rate. The removal of the film of cathodic hydrogen causes depolarization and increases the corrosion rate. Chemical reactions can

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cause depolarization (as, for example, in the reaction between dissolved oxygen and nascent cathodic hydrogen). This reaction is slow in the absence of a catalyst, but may be accelerated markedly by bacteria which catalyze the reaction.

The ferrous hydroxide also tends to form an alkaline protective film on the metal surface. Processes which tend to remove this film, such as an increase in hydrogen ion concentration (decrease in pH) or the oxidation of ferrous hydroxide to hydrated ferric oxide, also would tend to increase the rate of corrosion.

Corrosion is accelerated also by concentration cells created when the metal surface is immersed in a solution with varying concentrations of chemicals such as oxygen, hydrogen sulfide, or salts.

Inasmuch as solution of metal takes place only at anodes, it is possible to eliminate corrosion by making the entire area of a piece of metal cathodic. This is accomplished in the practice of cathodic protection by connecting the metal equipment to be protected to a metal which is lower in the electromotive series; for example, steel equipment is connected with wires to a sacrificial anode of magnesium or zinc buried in the ground or immersed in a liquid in which the cathode is contained. Another means of cathodic protection is to connect the positive pole of a direct current source to the item to be protected, and the negative pole to ground.

Mechanical Factors

Where different metals are in contact, the one lower on the electromotive series will become anodic and corrode. This factor must be taken into account in the construction of metal equipment. Protective coatings of paint, tar, or plastic may be used to good advantage in order to prevent corrosion. The motion of a metal surface immersed in water, or the motion of water flowing over a metal surface may be an important factor in corrosion. The turbulent action of flowing water can remove the film of molecular hydrogen and of ferrous and ferric hydroxides, and even may cause concentration cells to develop.

Microbiological Factors

Microorganisms, including bacteria, yeasts, molds, algae, and protozoa, can influence many of the electrochemical and mechanical factors named above, so that they may either increase or decrease the rate of corrosion.

Bacteria, because of their higher multiplication rate and versatility in chemical transformations are usually more important in corrosion than other microorganisms. Virtually all natural surface waters contain bacteria. The sea, lakes, rivers, and the soil are abundantly supplied with bacteria and other microorganisms which carry on activities which sometimes are of the greatest benefit to mankind and other times which are harmful. They grow at temperatures of from 30 to 180 F, and at hydrostatic pressures up to 15,000 psi. The pH range over which bacteria may exist is from at least 1.0 to 10.5.

Some bacteria (aerobes) require dissolved oxygen. Others (obligate anaerobes) function only in the ab-

sence of oxygen. Some bacteria (heterotrophic) utilize organic matter as a source of energy. Others (autotrophic) oxidize inorganic substances as energy sources, and utilize carbon dioxide as a carbon source. Because of this remarkable versatility, there are many ways in which microorganisms may contribute to corrosion. ZoBell⁷ presented the following list of processes by which organisms affect corrosion:

1. Through mechanical activities such as chewing, scraping, abrading, or coating metal surfaces.
2. By affecting electrochemical conditions (for example galvanic cell action and surface charges).
3. By affecting pH or acidity.
4. By affecting redox potentials.
5. By changing the chemical composition of the environment (by catalyzing the reactions involving ammonia, nitrate, nitrite organic matter, sulfate, sulfide, carbonate, iron, manganese, and other ions).
6. By affecting oxygen tension through the production or consumption of oxygen.

It is clear that many of these factors work together in contributing to corrosion, and it would be difficult to separate them and determine the extent to which each factor influences corrosion in a given situation. Because of their high level of metabolism and their versatility, microorganisms, especially bacteria, ordinarily are more important in corrosion than the larger macroorganisms. Several examples taken from the literature will be given in order to demonstrate how some of these factors operate to accelerate corrosion.

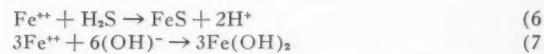
Examples of Microbiological Corrosion

The complex nature of microbiological corrosion renders any exact classification of types of corrosion according to the specific microorganisms involved difficult or impossible. Only one type of corrosion, anaerobic bacterial corrosion, is believed to be caused by specific microorganisms (the sulfate-reducing bacteria). Even here it is probable that other bacteria often are associated with the sulfate-reducing bacteria and may play a role in corrosion.

Anaerobic Corrosion Reactions. Anaerobic corrosion has received more study than any other type of microbiological corrosion. Von Wolzogen Kühr and Van der Vlugt⁶ have presented an explanation of anaerobic bacterial corrosion which is generally accepted today. They concluded that anaerobic corrosion is caused by the bacterial oxidation of hydrogen and reduction of sulfate according to the following reaction:



This reaction depolarizes the cathodic areas and accelerates corrosion. The formation of H₂S also may increase corrosion. The corrosion products are formed according to the reactions:



The following equation summarizes the process:



Equation 5, the oxidation of cathodic hydrogen,

was confirmed by Starkey and Wight⁵ using enrichment cultures, and by Butlin, Vernon, and Whiskin (1952)⁶ employing pure cultures of sulfate-reducing bacteria. Analysis of the corrosion products has confirmed that the corrosion product is a mixture of Fe(OH)_2 and FeS .

Pipe Line Corrosion. Hadley⁷ investigated the corrosion of pipe lines in Pennsylvania, Ohio and New York. He found a good correlation between corrosion rate and the type of soil in which the pipe was buried. Corrosion was at its worst in low, swampy areas where the soil pH lay between 6.2 and 7.8. In such areas pipelines corroded out in seven years, on the average.

Examination of the corroded pipes showed a black mass of corrosion products on the outside of the pipe consisting of ferrous hydroxide and ferrous sulfide. A cultural test for the presence of sulfate-reducing bacteria correlated well with the presence of the black corrosion product. The author concluded that sulfate-reducing bacteria are second only to stray-current electrolysis as a cause of pipeline failure.

Sulfate-reducing bacteria may contribute to the corrosion of oil well casings in the same manner. Doig and Wachter⁸ described casing corrosion in a California oil field at depths of from 900 to 7000 feet subsurface. Small holes were eaten through the $\frac{3}{8}$ -inch thick casing in an average time of 55 months. It was found that sulfate-reducing bacteria associated with the black corrosion products. Wells drilled with near-neutral drilling fluids showed a high incidence of this type of corrosion, but wells drilled with strongly alkaline drilling muds (pH 11 and above) showed a much lower frequency.

Other Functions of Bacteria. While the role of bacteria other than sulfate-reducing bacteria in anaerobic corrosion has not been made clear, there are several which may be important. Certain methane-producing bacteria carry out the reaction:



This reaction would depolarize cathodic areas. Other bacteria produce corrosive organic acids from carbohydrates and still others produce hydrogen sulfide from proteins.

Under aerobic conditions many more factors come into play and the picture becomes more complex. Aerobic bacteria can attack and decompose certain bituminous protective coating material and other organic materials which are relatively stable under anaerobic conditions.

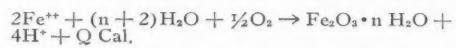
All aerobic bacteria consume oxygen, transferring it to organic matter, hydrogen, or other reduced substrates. This process may result in more reducing conditions in a localized part of an iron or steel surface. This difference in oxygen concentration establishes an oxygen concentration cell with an anodic area in the region of oxygen deficit and a cathodic area in the region of higher oxygen concentration.

Water Pipe Tubercles. Olsen and Szybalski⁹ described such a condition in a paper on aerobic micro-

biological corrosion of water pipes through which fresh water was flowing. Examination of the inner surface of the pipe disclosed many dark brown tubercles of considerable size. They were porous and easily cut by a knife, and consisted of a dark-colored to black core surrounded by stratified layers of lighter colors, with a rust-colored outer layer.

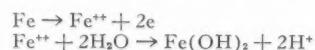
The metal beneath the tubercle corroded rapidly, leading eventually to a perforation of the pipe. Butlin et al¹⁰ tell of tubercles as large as footballs having been formed in this manner inside water mains in England. In old mains the sheer mass of the corrosion products and the associated bacteria may clog the pipes.

Careful microscopic examination by Olsen and Szybalski showed that the tubercles contained amorphous ferric hydroxides and many typical bacterial sheaths of ferric hydroxide from the iron bacterium, *Gallionella ferruginea*. Material from the tubercles, when inoculated into sterile tap water with a nail as an iron source, gave rise to a thread-like growth of *Leptothrix sp.*, another iron bacterium. The iron bacteria derive their energy for growth according to the following reaction:



Differential Aeration Cells. From the preceding discussion, it would be expected that the oxidation of ferrous hydroxide to ferric hydroxide might increase the corrosion rate. However, Olsen and Szybalski and von Wolzogen Kühr and Van der Vlugt believe that this effect is of little importance in the corrosion process. Olsen and Szybalski attributed the corrosive action of the bacteria in this case to a mechanical strengthening of the tubercle. This leads to the establishment of a differential aeration cell with an anodic area under the tubercle, where oxygen access is restricted, and a cathodic area on the metal adjacent to the tubercle. As conditions within the tubercle become more anaerobic, the potential difference between the metal within the outside the tubercle increases, and hence the corrosion rate is increased.

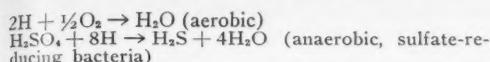
Olsen and Szybalski noted also that the pH within the tubercle varied from 5 to 6 and was lower than that of the surrounding water. This was attributed to the anodic solution of iron:



The acidity thus produced within the tubercle would be maintained because of the mechanical entrainment by the bacterial-tubercle mass.

Other Bacteria. Von Wolzogen Kühr and Van der Vlugt made a more thorough microbiological study of this type of corrosion. Their microscopic and cultural examinations revealed that in addition to iron bacteria, two other important groups of organisms were to be found in the tubercles: aerobic hydrogen-oxidizing bacteria and anaerobic sulfate-reducing bacteria.

These organisms catalyze the following reactions:



Thus cathodic hydrogen could be oxidized rapidly by both of these types of bacteria, leading to an increase in corrosion.

The sulfate-reducing bacteria also can grow by utilizing organic matter synthesized by the iron bacteria and aerobic hydrogen bacteria, producing H_2S and reducing the oxidation reduction potential, thus further promoting corrosion. Even though the running water in the mains contains dissolved oxygen, these obligately anaerobic bacteria can grow within the tubercles. This is because the aerobic bacteria utilize the oxygen and reduce the oxidation-reduction potential to a level suitable for the growth of sulfate-reducing bacteria.

Six Mechanisms. It can be seen that the description of one common type of corrosion (the internal corrosion of iron or steel water pipes) has involved each of the six general mechanisms listed by ZoBell by which organisms can influence corrosion. In this particular case present knowledge is too limited to permit evaluation of the relative importance of the different mechanisms, although it is known that the iron bacteria play a major role.

Again, as in the case of anaerobic corrosion, there are many other bacterial processes which may be of importance in aerobic corrosion but which have received little study. Sulfur bacteria, for example, oxidize hydrogen sulfide, sulfur, and other sulfur compounds to sulfuric acid. Beckwith¹¹ described cases where sulfur-oxidizing bacteria produced so much sulfuric acid that the pH dropped to 0.8. Nitrosifying bacteria oxidize ammonia to nitrous acid, and nitrifying bacteria oxidize nitrous acid to nitric acid. These acids, if not neutralized immediately, act to corrode the metal.

Prevention of Microbiological Corrosion

As pointed out above, microbiological corrosion has been known for many years. It was not until recently, however, that serious efforts were made in the United States to combat this type of corrosion. The field is now one in which many oil companies, oil field service companies and chemical companies take an active interest. Many excellent germicides designed for use in this connection are on the market.

In addition to the use of germicides or inhibitors, many other means are at hand for preventing or lessening the corrosive effects of microorganisms. Removal of sulfate from the water will prevent the growth of sulfate-reducing bacteria, as will thorough aeration of the environment.

Cathodic protection is effective in nearly all cases, although Beckwith believed that it may not always be effective against sulfate-reducing bacteria. However his experiments were limited to the use of very low voltages and currents, and it is probable that a sufficiently high current would prevent bacterial corrosion. Sulfate-reducing bacteria carry out activi-

ties which would increase the current required for protection.

Protective coatings and corrosion resistant alloys are good remedies under some conditions. Selection of the anti-corrosion measures to be used in a given situation is a difficult job necessitating an evaluation of all the mechanical, electrochemical, and microbiological factors involved. It also is necessary to make an economic comparison of the various possible treatments in order to get a maximum of protection per dollar invested. The methods of choice for control of microbiological corrosion will differ markedly in different locations.

Oil Well Protection

For example, in the highly corrosive marine environment the treatment of choice would be protective coatings and cathodic protection. Drilling muds, used in oil-well drilling, can be treated with alkali to a pH of 11 to 14 so that the development of all bacteria in contact with the mud will be inhibited. The alkali is used to improve the physicochemical characteristics of the mud, and bacteria control is a fortunate coincidence. Under certain drilling conditions when high pH muds are undesirable, it is advisable to use a germicide in the mud. Investigations of more than 100 chemicals show that the chromate ion, long used as a general corrosion inhibitor, is also effective in drilling muds. It is used at a level of 500 parts per million, to prevent the development of sulfate-reducing bacteria.

Oil field equipment exposed to water frequently is attacked by bacterial corrosion as well as by chemical corrosion caused by oxygen, carbon dioxide, and hydrogen sulfide. Menaul and Dunn¹² and Latter¹³ recommended formaldehyde for reducing hydrogen sulfide corrosion of the casing, tubing, and sucker rods in producing oil wells and associated equipment. Menaul and Dunn found that KCN was also effective, although six other relatively nongermicidal substances were ineffective. Inasmuch as laboratory investigations have shown that formaldehyde^{14, 15} and cyanide¹⁶ are effective inhibitors of sulfate-reducing bacteria at levels between 10 and 50 parts per million of water, it is not unlikely that the beneficial effect of these substances may have been due, at least in part, to their antibacterial action. Menaul and Dunn, however, attributed their effectiveness to chemical film formation.

Breston and Barton¹⁷ found that "rosin" amine acetate at two to four parts per million reduced the bacterial count of oil-field flooding waters as well as their corrosivity; recent information indicates that this compound is a poor germicide.¹⁸

Heck, Barton and Howell¹⁹ field-tested "rosin" amine acetate and two quaternary compounds, alkyl dimethyl benzyl ammonium chloride and alkyl trimethyl ammonium chloride as inhibitors of acid corrosion and found them to be effective, and Breston¹⁹ found them to be good agents for preventing bacterial growth in flooding waters. Chlorination, long used to kill bacteria in water, is of little use against anaerobic bacteria which cause corrosion because the sulfide produced by the bacteria inactivate the chlorine.

Selecting a Germicide

Allred²⁰ presented an excellent discussion of the factors to consider in choosing a germicide for controlling microorganisms in water flooding. The most important considerations are efficiency of inhibiting microorganisms and economic factors. Other matters of importance are toxicity to humans and animals, ease of handling, solubility in water as a function of pH and salt concentration, and relative solubility in oil and water. The quaternary ammonium compounds dimethyl "dicoco" ammonium chloride and trimethyl "soya" ammonium chloride at levels of 5 to 20 parts per million were recommended for the control of sulfate-reducing bacteria, except where the water was contacted with oil (as in oily sand filters). In this case much of the germicide was lost because of its greater relative solubility in oil. Sodium tetrachlorophenate, at 15 parts per million, was recommended for use under such circumstances because of its lower relative solubility in oil.

Tests have established that many germicides now on the market are excellent for inhibiting sulfate-reducing bacteria. Many quaternaries are good, although rather high priced. Certain high molecular weight aliphatic primary amines, tetrachlorophenol, pentachlorophenol and glyoxal are also highly effective, and sell for a lower price than most, if not all, quaternaries.

The choice of a germicide for treating a water flood should be made by a competent microbiologist after completion of a thorough study of the individual flood, including bacteriological analysis of samples of water, corrosion scale, and sediments obtained from the field system.

Allred et al²¹ described a method of analyzing such samples for sulfate-reducing bacteria. It should be emphasized, however, that many other types of bacteria may be at least as important in corrosion as the sulfate-reducing bacteria. In this connection, it should be recognized that the plugging of water injection wells by bacteria and their products, such as iron sulfide, and iron hydroxides, may constitute a more serious problem than bacterial corrosion. Iron bacteria, and other slime producing microorganisms, are sometimes very troublesome in this connection. A germicide treatment should be designed to overcome both bacterial corrosion and bacterial plugging;

this may be a difficult thing to accomplish without considerable skilled technical work.

There is a definite need for more basic information on the roles played by different types of microorganisms in corrosion and in the related problem of bacterial plugging. The microbiologist, in treating a problem in microbial corrosion or plugging faces a problem similar to that of a physician treating a patient with an infectious disease. As with disease-producing bacteria, the water bacteria responsible for the "ills" of corrosion and plugging will develop resistance to the germicides and inhibitors used. Because of this it is necessary to be prepared to switch to new and different inhibitors as soon as examination of the water shows that the old one is no longer effective. The chemical industry fortunately has supplied the microbiologists with a large number of effective products from which a choice may be made.

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*Any discussions of this article not published above
will appear in the December, 1955 issue.*

Air Injection for Prevention of Hydrogen Penetration of Steel*

By W. A. BONNER and H. D. BURNHAM

Introduction

HYDROGEN damage to steel has received much attention in natural gasoline plants and refinery gas compression and processing equipment.^{1, 2, 3, 4} This discussion is concerned only with hydrogen produced as a result of a corrosion reaction of steel with hydrogen sulfide at or slightly above atmospheric temperature. It is not concerned with high temperature hydrogen attack nor with attack in sulfuric or hydrofluoric acid units.

As the economic loss resulting from hydrogen damage to refinery equipment increased, investigations of some of the variables associated with hydrogen attack were initiated with particular emphasis on the corrosion reactions which produce atomic hydrogen. This work established the nature of the corrosion problem involved and enabled the prediction of a solution which was successfully demonstrated in both laboratory and plant-scale tests.^{5, 6}

Following publication of the efficacy of polysulfide in the control of hydrogen penetration,⁵ much interest was shown by companies experiencing hydrogen attack in similar equipment. Many inquiries were received concerning the details of the application and control of air injection into the hydrogen streams. This paper discusses the difficulties associated with air injection and touches on the solutions to those problems. Methods that have been developed for control of air injection are presented along with a summary of refinery experience with this technique for the control of hydrogen penetration in an actual operating unit.

Experience With Methods Other Than Air Injection

Several methods for minimizing hydrogen damage were attempted in the plant. In one instance, a replacement vessel of ASTM A-201, "B" steel was installed. This vessel blistered lightly within a year, indicating that even cleaner steels were not sufficiently resistant to hydrogen damage. Commercial organic corrosion inhibitors and pure organic compounds known to be useful as inhibitors in acidic systems have been tested in both the laboratory and plant. During the plant tests, hydrogen probe activity dropped perceptibly but inspection of equipment revealed many additional blisters had developed during the trial period.

At one refinery organic and inorganic coatings designed to prevent penetration of atomic hydrogen into steel were shown to be unsatisfactory because



W. A. BONNER—Corrosion Engineer with the Shell Oil Company, Wood River, Illinois. He received BS in chemistry from the University of Tennessee and an MS from Purdue University. Formerly employed by Shell Development Company, he was transferred to Shell Oil Company where his duties have included plant problems and process evaluations. Since 1951 he has been working with process corrosion problems.



H. D. BURNHAM—Research Laboratory staff member, Shell Oil Company, Wood River, Illinois. Dr. Burnham is a native Californian and a graduate of the University of California at Berkeley; in 1940 he received a PhD from Princeton University. Dr. Burnham's primary interest has been in the application of physical measurements to the solution of analytical problems. These studies have included measurement of electrical and optical properties, deposits in internal combustion engines, X-ray diffraction and X-ray fluorescence and corrosion.

Abstract

The use of very small amounts of air for the prevention of hydrogen attack leading to blistering and fissuring of equipment is described. This protection is achieved by producing a small amount of polysulfide in situ which converts cyanide to thiocyanate and inhibits the primary corrosion reaction. The method has been used successfully for about two years. Inspections have failed to show any hydrogen damage to equipment protected by adequate air injection; no degradation of product quality has been observed.

In the application of the method, a number of problems arose which have since been solved. These difficulties include: 1) accumulation of oxygen in stagnant vapor areas, 2) accumulation of acidic ammonium thiocyanate leading to high corrosion rates, 3) control of pH in the desired range to prevent deposition of ammonium salts and to prevent decomposition of ammonium polysulfide, and 4) limited reaction rate between oxygen and hydrogen sulfide to form polysulfide.

Several methods are considered for the control of air injection to meet the polysulfide requirement in the system. Hydrogen penetration probes and chemical spot tests for ferrocyanide and free cyanide have been found adequate for this purpose. Complete protection against hydrogen damage has been attained by only infrequent adjustment of the air injection rates.

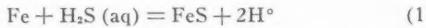
of the failure of the coating to form an impervious barrier. Expendable steel liners have been successful but their application has been limited because of the time and effort required for installation. Cement-type

*A paper presented at the Eleventh Annual Conference, National Association of Corrosion Engineers, Chicago, Illinois, March 7-11, 1955.

linings are readily applied and have protected the vessel walls adequately for several years where the water accumulations were alkaline. However, lines and condensers cannot be protected in this manner. Since it has been found that polysulfide will prevent the primary corrosion reaction and resultant hydrogen penetration, the above type of protective linings are not widely used.

Description of Corrosion Process

The primary corrosion reaction under refinery conditions which occurs on steel in an aqueous layer saturated with hydrogen sulfide is given in the equation:

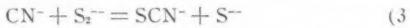


When iron corrodes in the absence of sulfide, the combination reaction, equation (2), is fast and molecular hydrogen escapes from the steel surface.

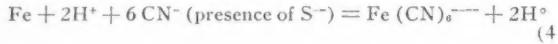


In the presence of sulfide, however, the combination reaction, equation (2), is slow and the concentration of atomic hydrogen builds up on the surface. As a result of the high surface concentration, atomic hydrogen penetrates the steel in which it is slightly soluble. The atomic hydrogen diffuses through the steel, collects at discontinuities or defects, and combines to form molecular hydrogen. In alkaline systems under anaerobic conditions, the corrosion reaction, equation (1), continues indefinitely with the ultimate formation of blisters and fissures in the steel.

The sulfide corrosion reaction, equation (1), can be stopped by the addition of polysulfide or materials such as oxygen, free sulfur or ferric ion, which lead to the formation of polysulfide in alkaline aqueous solutions. Having been stopped in this manner, the corrosion and penetration can be started again by adding a polysulfide scavenger such as finely-divided ferrous sulfide or cyanide. The cyanide reacts preferentially with polysulfide according to the equation:



Excess free cyanide promotes corrosion and hydrogen penetration with the formation of ferrocyanide, equation (4):



With cyanide concentrations in the range of 1.0 gram per liter in the aqueous phase, very high hydrogen penetration rates have been observed in laboratory experiments. However, free cyanide concentration of this magnitude has not been found in refinery streams.

Polysulfide is non-volatile and, therefore, can protect only those areas with which it comes in direct contact. However, it is possible to form polysulfide in situ by injecting air into a gas stream containing hydrogen sulfide. Sufficient ammonia must be added so that the pH of any water accumulation will be 7.8 or above.⁵ The reaction of oxygen and sulfide ions is

relatively slow and incomplete under the usual gas plant operating conditions. Oxygen remains in the gas stream and forms polysulfide in the numerous process vessels which follow the point of air injection.

Difficulties Associated With Air Injection

Several difficulties associated with air injection into hydrocarbon streams have arisen. These problems have been overcome satisfactorily in the plant. A knowledge of the possible difficulties and the solutions should be useful to anyone attempting to use the process.

Effect of Air on Product Quality

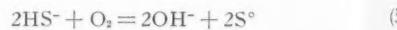
When air injection for the control of hydrogen attack was first considered for the plant processes, it was necessary to establish immediately whether there were any deleterious effects on product quality. ASTM gum contents of the gasolines were watched closely during initial periods of air injection and compared to gum contents observed during periods of no air injection. The air rate was varied from 0.1 to 1.0 SCFM (standard cubic feet per minute) per million SCFD (standard cubic feet per day); gas and the process temperature at the points of injection ranged from 90 to 350 F. No change in ASTM gum content of the gasoline has been observed since air injection was started.

During the first pilot plant trial with polysulfide when the pH of the accumulator water dropped to approximately 7.5 for a period of several hours, evidence of elemental sulfur contamination of hydrocarbon was obtained. At 7.8 pH or above, the sulfur forms the water-soluble hydrocarbon-insoluble ammonium polysulfide. Elemental sulfur from air oxidation of hydrogen sulfide has not been found as a contaminant of any product when the pH is maintained above this value.

Accumulation of Oxygen

The first point of air injection was ahead of the gas compression stages at the rate of one SCFM per million SCFD hydrocarbon gas. This rate was estimated to be five times that of the theoretical requirement to convert all cyanide to thiocyanate.⁵ A moderate amount of hydrogen probe activity was observed in the final unit of the gas processing plant, depropanizer reflux accumulator. An attempt was made to determine the effect of a large excess of oxygen. Subsequent experience has demonstrated that a large excess of air was not only unnecessary, but objectionable.

Oxygen in the gas stream can react with the hydroxide ion according to equation (5) to produce elemental sulfur which, in turn, will complex with a sulfide ion to produce the polysulfide ion as shown in equation (6):



Polysulfide reacts with cyanide (equation 3) and inhibits hydrogen penetration. The reaction rate of equation (5) is slow; in case there is little hydrogen

sulfide and relatively low gas flow, oxygen can accumulate in stagnant vapor areas. This local excess of oxygen itself can lead to hydrogen penetration. This condition was detected by activity of probes located in the vapor area of the depropanizer accumulator during a trial period of high air injection. Air injection ahead of the compression stages was maintained throughout this test period.

The probe activity during this plant experiment is shown in Figure 1. Prior to air injection, probe activity was high and ferrocyanide was detected in the accumulator water samples. At point (a, Figure 1), a large excess of air was injected amounting to roughly 12 SCFM per million SCFD gas. Spot tests on water samples had been positive for ferrocyanide for 24 days prior to start of air injection. About a day after air was started, probe activity had almost stopped. Ferrocyanide was not present the second and succeeding days following start of air injection. Copious quantities of polysulfide were present in the water phase. After about four days, however, probe activity began to increase. At point (b, gas analysis indicated a 0.7 percent oxygen by volume in the vapor space; air injection into this unit was discontinued. Probe activity began to diminish slowly. Changes in processing equipment and operating conditions in units ahead of the depropanizer have since eliminated the necessity of air injection at this point.

A complete explanation for the increase in hydrogen penetration due to the accumulation of excess oxygen in the above instance cannot be given. One possibility is that a local deficiency of hydrogen sulfide developed which allowed undesirable side reactions to occur. Laboratory experiments using excess oxygen with active accumulator water showed hydrogen penetration and some rusting of the metal in the stagnant vapor areas. No hydrogen penetration was observed in the section contacted by accumulator water which contained excess hydrogen sulfide and polysulfide. A second possibility would be the development of localized acidic conditions due to oxidation of sulfides to sulfates. Substantial quantities of sulfate have been detected intermittently in accumulator water where contamination with wash water was not possible.

Accumulation of Ammonium Thiocyanate

During the early plant trials of air injection, the removal of ammonium thiocyanate from the processing equipment received little attention. After several weeks' operation, corrosion products, ferrous sulfide and iron thiocyanate appeared on suction screens and obstructed the hydrocarbon flow from the bottom of an adsorption column. The water accumulation was very small and the pH ranged around 5.0. On cooling a sample of accumulated water from a column, a crystalline material was formed which was removed and identified by x-ray diffraction as ammonium thiocyanate. Apparently the design and operation of the column prevented am-

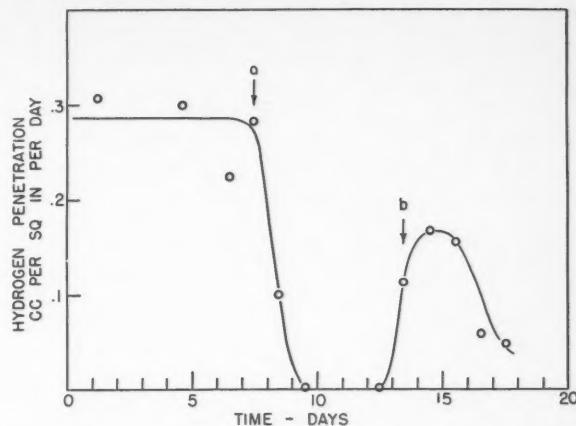


Figure 1—Effect of local excess air on probe activity (depropanizer accumulator, September 2-20, 1953). Air injection was started at point (a) and discontinued at point (b).

monium thiocyanate from being removed from the bottom under normal processing conditions. At about the same time, a reciprocating compressor which was processing gas to which air had been added, was found to have severely corroded low carbon steel valve seats. Deposits on the valve seats were found to be ferrous sulfide and iron thiocyanate.

As a result of the above difficulties, air injection was stopped pending the outcome of the laboratory investigation of the effect of ammonium thiocyanate on the corrosion rate of steel. In this laboratory work, samples of A-285 Grade C low carbon steel and Inconel were used as test specimens. The effects of pH, temperature, concentration of ammonium thiocyanate and presence or absence of air on the corrosion rates are summarized in Table 1. These tests were performed in solutions prepared from technical grade ammonium thiocyanate, distilled water, ammonium hydroxide and hydrogen sulfide. A stream of hydrogen sulfide at one atmosphere was bubbled through the solution at all times. A small amount of air was mixed with the hydrogen sulfide in those experiments designated as containing air.

The data in Table 1 show that ammonium thiocyanate can cause high corrosion rates in the presence of air or polysulfide at elevated temperatures in both acid and alkaline solutions. However, if the concentration of ammonium thiocyanate is kept below approximately 10 percent w, and the pH is maintained above 7.8, corrosion rate is very low even

TABLE 1—Effect of Temperature, Concentration of Ammonium Thiocyanate and the Presence of Air on Corrosion Rates in Ammonium Thiocyanate Solution at 1 Atmosphere H₂S Partial Pressure

Ammonium Thiocyanate, Percent w...	Corrosion Rates in Mils per Year									
	10					30			Saturated	
	pH Range*	7.3 ± .1	8.4 ± .1	7.4 ± .1	8.4 ± .1	5.4 ± .1				
Temperature, °F.....	85 85 190	85 85 190	160 160	160 160	85 85 195					
Air Present.....	No Yes Yes	No Yes Yes	No Yes Yes	No Yes Yes	No Yes Yes					
A-285 Grade C Steel.....	1 < 1 200	7 < 1 2	5 200	4 200	10 20 500					
Inconel.....	** < 1 < 1 < 1	4 < 1 < 1	< 1 < 1	< 1 < 1	...					

* Ammonium hydroxide added to the ammonium thiocyanate solution to produce these pH's after saturation with hydrogen sulfide.
** < = less than.

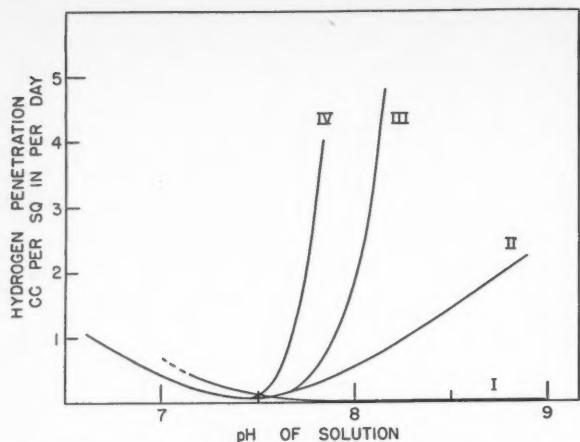


Figure 2—Effect of polysulfide and cyanide on hydrogen penetration. Measurements are made in solution of ammonium hydroxide and one atmosphere hydrogen sulfide; temperature is approximately 100 F. Curve I is with air or polysulfide; Curve II is with no cyanide and no polysulfide; Curve III is with 0.03 percent weight cyanide; Curve IV is with 0.10 percent weight cyanide.

at a temperature of 190 F. Fortunately, ammonium thiocyanate is very soluble and can be removed from processing equipment by washing with small amounts of water.

Facilities were installed to wash with three to five gallons of water per minute at the absorption column. Air again was injected ahead of the low pressure compression stages and the ammonium thiocyanate content of the water wash observed. Subsequent inspections have shown no further corrosion since water wash for the removal of ammonium thiocyanate began.

It should be pointed out that while the hydrogen which penetrates the steel and produces the blistering is a product of a corrosion reaction, the actual loss of metal is not a problem. Thus, even in severe cases of blistering, a maximum corrosion rate of only three mils per year was observed during the service life of the vessel.

Importance of Maintaining Optimum pH

The effect of pH on the penetration rate observed when a standard probe is immersed in ammonium hydrosulfide solution alone, ammonium hydrosulfide plus ammonium cyanide, and ammonium hydrosulfide plus ammonium polysulfide solution is shown in Figure 2. In the absence of air or polysulfide, a minimum hydrogen penetration is found in the range of 7.3 to 7.8. With air injection and consequent excess polysulfide formation, the penetration rate essentially vanishes for all pH's above about 7.8. While this sets the lower limit at 7.8, the upper limit is imposed by the deposition of solid salts in the operating equipment.

At a number of locations in the plant, ammonia injection is used to maintain the desired pH. Under some operating conditions, the ammonia requirement may be relatively high. As a result, ammonium bicarbonates have deposited in tubular equipment and lines. Both ammonium bicarbonate, NH_4HCO_3 , and ammonium carbonate monohydrate, $(\text{NH}_4)_2\text{CO}_3 \cdot \text{H}_2\text{O}$, have been identified by X-ray diffraction in such de-

posits. Ammonium bicarbonate deposition increases with the partial pressure of carbon dioxide, partial pressure of hydrogen sulfide and pH. On the other hand, solubility increases with temperature. Theoretical consideration of these variables has shown that a small change in pH has a relatively large effect on ammonium bicarbonate deposition. This is fortunate because pH is usually more readily controlled than the other variables. Thus, to minimize both hydrogen penetration and hazards of solid salts depositing with the existing gas composition, operation in the pH range of 7.8 to 8.3 is required. No recurrences of ammonium bicarbonate deposition have occurred in the plant since this upper pH limit was specified.

Slow Reaction Rate of Air With Hydrogen Sulfide

Qualitative laboratory experiments have shown that oxidation of the sulfide ion to elementary sulfur and the consequent formation of polysulfide is a relatively slow process. On the other hand, the ionic reaction between polysulfide and cyanide in solution is rapid. The rate of reaction between sulfide and oxygen increases with pH such that in the pH range 7.8-8.3, satisfactory control of hydrogen penetration is obtained with air injection alone in the refinery. If, however, unusually large quantities of cyanide were being produced or if the residence time of the air in the process stream were very low, then it is quite possible that the rate of formation of polysulfide would be insufficient to prevent hydrogen penetration in the equipment. A suggested procedure in this case would be to aerate some of the sour water available from the process and return it to the system as wash water in addition to air injection. The use of both polysulfide and air would be expected to reduce the free cyanide content more rapidly than air injection alone.

Experiences discussed above have been related to all-steel units as contrasted to plants employing Admiralty metal condenser tubes or other alloy equipment. Discussions with personnel from other companies have indicated that each plant may have its own particular problems. Successful application of air injection for the prevention of hydrogen attack at the Wood River Refinery has required (a) use of compressors with adjustable delivery rate, (b) water wash where condensation was inadequate to remove ammonium thiocyanate, (c) pH control in the range of 7.8-8.3 to obtain adequate polysulfide formation without bicarbonate deposition, (d) injection of air before the first compression stage to increase residence time in the system.

Control of Air Injection

It is desirable to have an excess of air in the system to protect against unusual conditions which may increase cyanide production. Actually, due to the short resident times at each stage in the system, equilibrium conditions are never attained. Thus, even with sufficient air theoretically to remove all cyanide, experience has shown that detectable free cyanide may remain in the gas streams. It is possible, however, to stop hydrogen penetration by having suffi-

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cient air in the gas to form polysulfide on the steel at a slightly higher rate than it is removed by cyanide.

Painted Test Can Technique

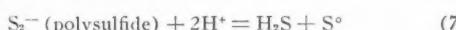
Substantially less hydrogen is required to blister a paint film than to blister steel. A sensitive method for detecting hydrogen penetration, known as the painted test can technique, was developed and described in a previous paper.⁵ This method has not been used on a routine basis for controlling air injection because of the time required to prepare the can and to observe qualitatively the extent of blistering of the paint film. Furthermore, the test lacks sensitivity when testing accumulator condensates which have been diluted appreciably with wash water.

Hydrogen Penetration Probes

Probes have been found to be more practical in following the occurrence of hydrogen penetration.¹ A hydrogen penetration probe is a short, thin-walled steel pipe with valve and pressure gauge. Several tests have been made using both painted test cans and probes simultaneously in the same solutions. Good correlation has been obtained between these two means of measuring hydrogen penetration. Once the probe has been installed in a vessel, frequent readings can be obtained with a minimum of effort. These readings can yield the actual penetration rates and supply a continuous record of conditions existing in the unit. The first probes were installed in the plant over four years ago and many of these original probes are still in service.

There are instances when a closer control of air injection rate is desired than can be achieved by observing probes. When the activity is low, the temperature correction and reading error tend to obscure the true penetration rate.

At times, probes have been observed to become active due to some unknown change in operating conditions. In these instances, a chemical test for polysulfide would be useful. When present in substantial concentrations, polysulfide may be detected by acidifying the accumulator water samples with development of visible turbidity due to free sulfur, equation (7):



This is not a sensitive test for polysulfide, and the presence of free sulfur by this method is not readily detected in the case of a borderline air injection rate.

It is known that the effectiveness of polysulfide in preventing hydrogen penetration in basic solution can be completely destroyed by the addition of stoichiometric amounts of cyanide. The polysulfide is converted to thiocyanate according to equation (3). In the Wood River Refinery catalytic cracking operations, 100 to 200 pounds of cyanide are produced each day. Sufficient polysulfide must be available to convert essentially all the cyanide which collects in the condensed water to thiocyanate in order to achieve protection against conditions favorable to hydrogen penetration. A sensitive test for free cyanide could thus be used to detect hydrogen blistering conditions.

On the other hand, methods for total cyanide plus thiocyanate such as the colorimetric pyridine-benzidine procedure⁷ are valueless in detecting hydrogen blistering conditions. In the absence of sufficient polysulfide, the cyanide can either dissolve ferrous sulfide or can attack the steel directly with the formation of the ferrocyanide ion according to equations (4 or 8).



These reactions are not instantaneous. Thus, when the cyanide ion is present in low concentrations, several hours are required for the formation of detectable amounts of ferrocyanide. In plant units where the gas stream is washed with water, the residence time for the water may be only a few minutes. Water drain samples from such units may well contain free cyanide and, hence, be conducive to a small amount of hydrogen penetration even though no ferrocyanide can be detected in the water sample taken directly from the unit.

Spot Test for Ferrocyanide

The hydrogen blistering tendencies of alkaline water samples from various refinery vessels can be checked by making two very simple spot tests on white filter paper. Only two reagents are required, dilute (approximately 0.02 molar) ferric chloride solution, and dilute ferrous sulfate solution. One or two drops of the water to be tested are placed on the filter paper and allowed to dry. During the drying step, hydrocarbons, hydrogen sulfide and ammonia are lost from the water sample. A drop of dilute ferric chloride solution is then placed alongside and allowed to run into the area covered by the water sample. This procedure reduces the interference from high concentration of thiocyanate, if present. Development of the ferric-ferrocyanide blue color (Prussian blue) indicates that insufficient polysulfide is available on the surface of the steel to prevent hydrogen penetration.

If this test for ferrocyanide ion is negative, an additional test for free cyanide should be made. This is done by adding a small amount of dilute ferrous sulfate solution to the water sample, tightly stoppering the full bottle and allowing the sample to remain in contact with the freshly precipitated ferrous sulfide for several hours. If a spot test then shows ferrocyanide, free cyanide sufficient to promote hydrogen penetration was present in the original sample.

The method requires only a few minutes of actual man time per sample. It also requires a minimum of equipment and thus can be made readily in the field. Several water samples can be tested simultaneously on a single sheet of paper; because the blue color is more or less permanent, the sheets of paper on which the tests are made constitute a record of the conditions of the plant.

The test is very sensitive for the ferrocyanide ion. This is probably because of a tendency of the ferrocyanide to concentrate in the forward edge of the spreading droplet. A concentration of 0.00005 moles of ferrocyanide per liter gives a readily visible blue

coloration even in the presence of 0.5 molar thiocyanate.

Several methods have been considered for control of the air injection rate to meet the polysulfide requirement in the system. The use of hydrogen penetration probes has been found more practical than the painted can technique. Chemical spot tests for ferrocyanide and free cyanide in water accumulations are especially sensitive in detecting unsafe conditions which require an increase in air injection rate. Successful plant operation with air injection has been achieved using these controls.

Summary of Refinery Experience

There are four small air compressors in the Wood River Refinery which have been in operation from one to two years. At the time the first compressors were started, probes were observed daily to follow hydrogen penetration rates. As the activities decreased, fewer readings were considered necessary. Currently, probes are read three times a week. In addition, spot tests for ferrocyanide and cyanide ions and pH of water samples are obtained on a weekly basis. In every case where the pH has been above 7.8 and the proper amount of air has been injected into the gas stream, the probe activity dropped to practically zero and ferrocyanide or free cyanide was no longer detectable in water accumulations.

Two air compressors are in service at the catalytically cracked gas system. Air is injected into the suction of the first compression stages. These units have been in operation for about two years. The combined amount of air delivered by these compressors is .2 SCFM per million SCFD gas. Based on the average cyanide make, this represents approximately twice the amount of oxygen required to convert cyanide to thiocyanate.

Although blistering in the thermally cracked gas system has not been as severe as in the catalytically cracked gas system, a progressive formation of blisters has been observed in condensers and accumulators. Air injection for the control of hydrogen penetration has, therefore, been required. Air compressors have been installed on two separate streams. The combined air injection rate of the two compressors, which have been operating about one year, is about .15 SCFM per million SCFD gas. This air rate is approximately six times that of the stoichiometric requirement. No difficulties have developed as a result of this excess air owing to the fact there are no stagnant vapor areas in the system.

It is realized that variations in cyanide and gas productions as well as system upsets will occur. These will lead to variable oxygen requirements and possibly to occasional sporadic probe activity with accompanying occurrence of ferrocyanide. Experience has indicated that minor probe activity (less than .1 cc per square inch per week) maintained for only two or three weeks on a standard probe or even high sporadic rates maintained over short periods are of little consequence in promoting hydrogen damage. Furthermore, following a change in air injection rate, several days may be required to re-establish equi-

librium. Thus, no attempt should be made to adjust the oxygen rate on a day-to-day basis.

Probe readings, air injection rates and spot tests are not an end in themselves but are used merely to detect operating conditions conducive to penetration. Only by actual equipment inspections can the success or failure of air injection for the control of hydrogen penetration be determined. To date, complete inspections of all units in the catalytically and thermally cracked systems have not been made. However, many of the individual units have been inspected and in no case has any unit shown additional attack after adequate air injection was started.

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DISCUSSIONS

Question by F. M. Watkins, Sinclair Research Laboratories, Inc., Harvey, Illinois:

When considering addition of air for control of hydrogen blistering, is it necessary to avoid equipment such as large volume accumulators wherein air might accumulate?

Reply by W. A. Bonner:

Air injection into a rapidly flowing gas or gas liquid hydrocarbon stream gives a homogenous mixture in the gas phase which will not cause difficulties in large accumulators so long as the pH is above 7.8 and the hydrogen sulfide content is more than twice the oxygen concentration. Some difficulty has been experienced with injecting air into a system with a very low gas flow even when the hydrogen sulfide content was several times the oxygen volume. In this case, the probes which were in the top of the vessel began to show activity even though a large quantity of polysulfide solution was being removed from the bottom of the accumulator. The difficulty was due to a partial stagnation of the gas stream rather than to the volume of the vessel.

Question by Dr. Carl H. Samans, Standard Oil Co. (Indiana), Whiting, Indiana:

Has there been any problem to getting reproducible results with the hydrogen probes? From some of Mr. Bonner's earlier papers we had gotten the impression that the probes were not too reliable as far as reproducibility of results was concerned.

Reply by W. A. Bonner:

We have found that reproducibility of probe readings has been a problem. For this reason, it has become customary to install hydrogen probes in duplicate wherever possible for the purpose of having a check. Many times one probe will show more activity than the other. We are inclined to accept the activity of the more active probe as the truer indication of blistering tendencies.

Remark by Andrew James Brislin, Esso Standard Oil Co., Bayway Refinery, Linden, New Jersey:

At Esso Standard Oil Company's Bayway Refinery, increased corrosion rates in catalytic light ends overhead equipment have been traced to higher final boiling points of the vacuum distilled gas oil being fed to the catalytic cracking unit. High boiling metallo-organic-nitrogen (porphyrin type) compounds are distilled in the heavy gas oil fraction and break down in the reactor section of the catalytic cracking unit. Metals, such as vanadium, iron, and nickel, are deposited on the catalyst, thus reducing its activity. Harmful nitrogen compounds are formed, which carry over into the light ends equipment. Here, corrosion damage is incurred.

Reply by W. A. Bonner:

We concur that hydrogen cyanide can be formed in the catalytic cracking operation and lead to increased corrosion and hydrogen penetration in the gas processing plants.

Question by Frank J. Bruns, Sinclair Research Laboratories, Inc., Harvey, Illinois:

What is the nature of the protective film which forms on steel when the sulfide stream is treated with air injection?

Reply by W. A. Bonner:

A protective film of iron polysulfide apparently forms on steel in the presence of hydrogen sulfide and polysulfide. Such deposits have been analyzed by X-ray diffraction and small quantities of iron disulfide and free sulfur have been detected. However, the bulk of the deposit has not been identified. The thin adherent film markedly reduces the corrosion rate. On the other hand, an iron sulfide film formed in basic solution under anaerobic conditions is soft, loosely held and readily sloughs from the corroding surface.

Question by Jerome M. Bialosky, Koppers Co., Verona, Pa.:

Have the authors experienced any fires as a result of air injection while the steel surfaces are covered with an iron-sulfide film?

Reply by W. A. Bonner:

No fires have been experienced as a result of air

injection into our plant streams. The amount of air injected is very small in comparison to the amount of oxygen required to reach an explosive hydrocarbon mixture.

Question by William W. Johnson, Port Arthur, Texas:

Mr. Bonner, have you had any experience in which you had probe activity but no sign of blistering on the vessel?

Reply by W. A. Bonner:

Yes. In several instances we have had probes which showed a reasonably high activity for short periods, say, up to about two weeks. The equipment was thoroughly inspected in the area near the probe without locating any hydrogen blistering or fissuring. Probes are sensitive devices for measuring hydrogen penetration. Therefore, blistering is expected only when high probe activity is maintained for long periods of time.

Question by Norman Temple Gourlie, East Alton, Illinois:

Is there any preference as to the location of hydrogen probes in regard to piping adjacent to a vessel or in the vessel itself? In other words, will hydrogen activity be more pronounced in an exchanger shell or vessel? The reason this question was asked is that it is usually easier to install hydrogen probes in piping than in exchanger shells or vessels.

Reply by W. A. Bonner:

It is possible that the most meaningful indication could be obtained from a probe in the shell itself; however, probes have not been installed in exchanger shells in our plants because of the difficulties involved. They have been preferentially installed in the manways of our vessels. Some probes have been installed in lines. We have had satisfactory operation from each type of installation.

Question by Henry Philip Zeh, Standard Oil Co. of California, San Francisco, California:

Is it necessary to introduce air at more than one point in a gas recovery system? Is aeration of sour water and reintroduction of this water to the gas recovery system considered desirable?

Reply by W. A. Bonner:

We believe that one point for air injection into each hydrocarbon stream is sufficient. While we have four small air compressors in operation, each supplies air to a separate stream of our gas compression and processing plant. Aeration of sour water and reintroduction of this water to the gas recovery system has been considered, but we have not found it necessary to resort to this procedure.

The Alloy Growth Rate of 0.25 Pound Electrolytic Tin Plate in the Temperature Range, 380-440 F*

By WILLIAM N. LAMBERT

Introduction

COMMERCIAL electrolytic tin plate that has been flow-brightened has a certain amount of tin alloyed with the iron of the steel base. The amount of alloy is of importance as it affects manufacturing operations.

The iron-tin compounds formed during tin plate manufacture may be increased substantially by the subsequent organic coating baking operations of the can manufacturer, even though the temperatures used are below the melting point of the tin (450 F). This paper reports the effect of time and temperature on the rate of growth of the alloy layer of 0.25 pound electrolytic tin plate at temperatures below the melting point of tin.

Experimental Method

Two lots of 0.25 pound electrolytic tin plate were investigated. The alloy tin and total tin weights, in pounds per base box, for the lots were:

1. Low alloy series; alloy tin .021 lb./BB (average for one side) total tin .26 lb./BB (both sides).
2. High alloy series; alloy tin .042 lb./BB (average for one side) total tin .27 lb./BB (both sides).

The base box is the estimative unit of area, 112 sheets of tin plate 14 inches x 20 inches or 62,720 square inches (both sides). Clean 3-inch x 6-inch panels were immersed in a constant temperature (plus 2 degrees, minus 0 F) oil bath for intervals ranging from 5 seconds to 30 minutes at the following temperatures: 380 F, 400 F, 420 F, and 440 F. The panels were quenched immediately upon removal from the bath. The heated samples and untreated blanks were analyzed for alloy tin and free tin. The 3-inch x 6-inch panels were cut consecutively and numbered from the center of a run of tin plate. The odd numbered panels were retained as untreated blanks and analyzed with the even numbered treated samples to insure that the initial alloy layer remained the same for each lot of tin plate.

Previous experiments indicated that constant temperature baths in which glycerine or palm oil were used dissolved tin at the experimental temperatures. To avoid loss of tin during heating, numerous oils were tested until one was obtained with a flash point above the testing temperatures and also as near neutral as possible (0.0 acid number). The analysis of the samples treated in the neutral oil

WILLIAM N. LAMBERT—Metallurgist with the Research and Development Department of Inland Steel Company, East Chicago, Indiana. He received a degree in metallurgical engineering from Carnegie Institute of Technology and attended the graduate school of Illinois Institute of Technology. His work is with research and development in the field of physical metallurgy of iron and steel.



Abstract

Quarter pound electrolytic tin plate was immersed from five seconds to thirty minutes in a constant temperature oil bath at four temperatures below the melting point of tin. The growth of the tin-iron alloy for each temperature and initial alloy layer was plotted, and from these data an equation was obtained for the rate of growth of the alloy layer.

showed no loss of tin except for the longer periods of 440 F where some loss of tin was observed.

Results

The results of the coating weight analysis after treatment are shown graphically in Figures 1 to 4 for both alloy series. The figures are for the experimental temperatures 380 F, 400 F, 420 F and 440 F respectively and show the average alloy coating for one side of the plate after various times at temperature. The points for the high alloy series at 440 F fell below the calculated line at the longer time periods. This resulted from the loss of tin at this temperature to where the samples became entirely or partially grey indicating that the alloy layer had penetrated to the surface and had used all of the available free tin. This was confirmed by the chemical analysis of the tin coating.

Time and Temperature in Growth Rate

The growth of the alloy layer at various periods was first studied as a log plot of Sn vs t_A . It was found that the curves were of the same general type that Seybolt¹ found for temperatures above the melting point of tin. The curves drawn for the data of each alloy and temperature, Figures 1 to 4, were of the type:

$$Sn = a(t_A + b)^n \quad (1)$$

Sn is the tin in the alloy layer, t_A is the time the

* Submitted for publication January 31, 1955.

panels were heated and a , b and n are constants for each curve. The values of the constants were determined from the log log plots and are shown on the curves of Figures 1 to 4.

The values of a and n were found to be linear with temperature over the small temperature range investigated (60 F). The temperature dependence of the constants and their values are shown in Figures 5 and 6 for each alloy layer. As only two base alloy layers were studied at this time, the values of the constants could not be expressed as a function of the alloy layer.

The rate of growth of the alloy can be expressed by differentiating the alloy layer curve equation, Equation (1), with respect to the time in the oil bath, t_A .

$$\frac{dS_n}{dt_A} = \frac{d}{dt_A} [a(t_A + b)^n] \quad (2)$$

However, the total alloy, S_n , is a sum of the initial alloy, S_{n_0} , which is constant for each base alloy and the diffusion alloy, S_{n_A} . Thus:

$$S_n = S_{n_0} + S_{n_A} \quad (3)$$

Substituting equation (3) into equation (1) and differentiating the equation:

$$\frac{dS_{n_A}}{dt_A} = an(t_A + b)^{n-1} \quad (4)$$

the rate of growth equation for the alloy layer is expressed as a function of time. In equation (1) the value of t_A is:

$$t_A = \left(\frac{S_n}{a} \right)^{1/n} - b \quad (5)$$

Substituting the value of t_A from equation (5) into equation (4) the rate of growth equation becomes:

$$\frac{dS_{n_A}}{dt_A} = an \left(\frac{a}{S_n} \right)^{\frac{1-n}{n}} \quad (6)$$

Equation (6) is, thus, the rate of growth equation as a function of the total alloy. It will be noted that the value of b is not essential to this final rate of growth equation making it unessential to calculate the temperature dependence of this function.

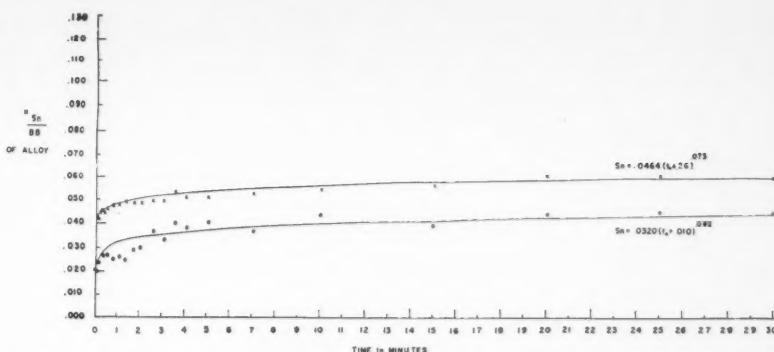


Figure 1—Growth of alloy layers at 380 F. On top curve, $Sn = .0464(t_A + .26)^{.073}$; on bottom curve, $Sn = .0320(t_A + .010)^{.092}$.

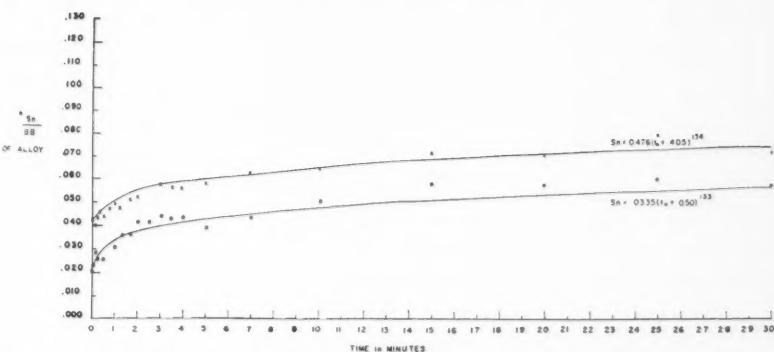


Figure 2—Growth of alloy layers at 400 F. On top curve, $Sn = .0476(t_A + .405)^{.134}$; on bottom curve, $Sn = .0335(t_A + .050)^{.153}$.

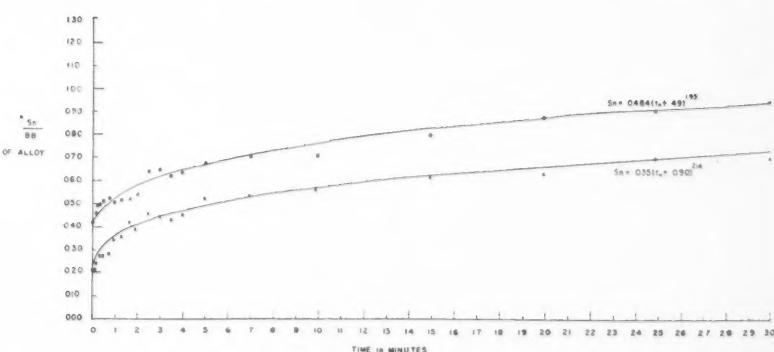


Figure 3—Growth of alloy layer at 420 F. On top curve, $Sn = .0484(t_A + .49)^{.195}$; on bottom curve, $Sn = .0351(t_A + .090)^{.214}$.

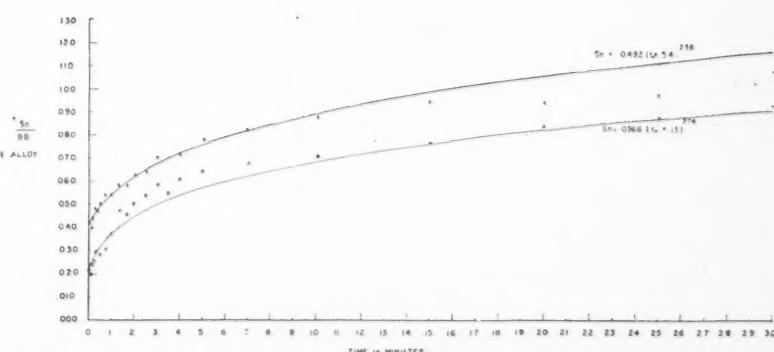


Figure 4—Growth of alloy layer at 440 F. On top curve, $Sn = .0492(t_A + .54)^{.256}$ on bottom curve, $Sn = .0366(t_A + .13)^{.276}$.

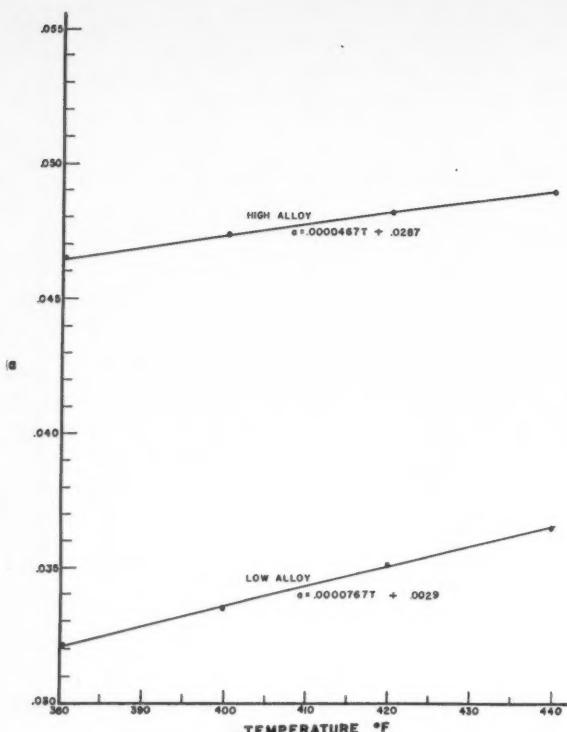


Figure 5—Temperature dependence of Constant "a".

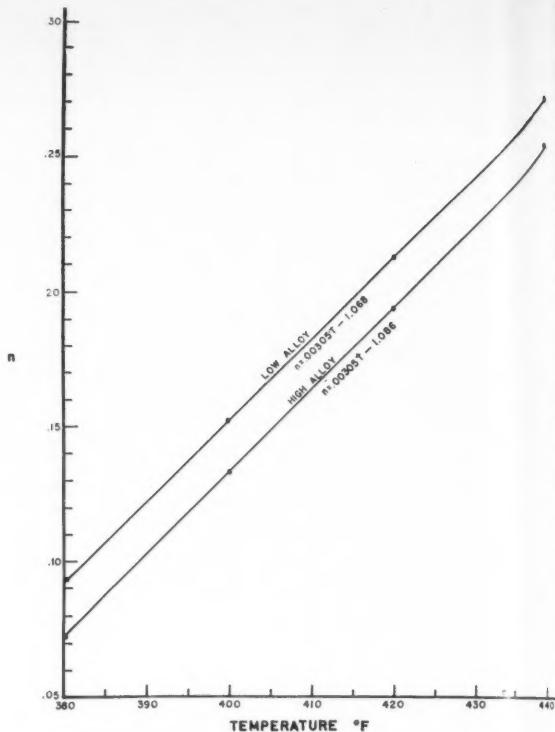


Figure 6—Temperature dependence of Exponent "n".

TABLE 1—Rate of Growth for Low Alloy Series (.021 lb./BB)

Temperature	Rate of Growth
380 F.	$\frac{d \text{Sn}_\Delta}{d t_\Delta} = .00234 \left(\frac{.0320}{\text{Sn}} \right) 9.870$
400 F.	$\frac{d \text{Sn}_\Delta}{d t_\Delta} = .00513 \left(\frac{.0335}{\text{Sn}} \right) 5.536$
420 F.	$\frac{d \text{Sn}_\Delta}{d t_\Delta} = .00751 \left(\frac{.0351}{\text{Sn}} \right) 3.673$
440 F.	$\frac{d \text{Sn}_\Delta}{d t_\Delta} = .0100 \left(\frac{.0366}{\text{Sn}} \right) 2.650$

TABLE 2—Rate of Growth for High Alloy Series (.042 lb./BB)

Temperature	Rate of Growth
380 F.	$\frac{d \text{Sn}_\Delta}{d t_\Delta} = .00339 \left(\frac{.0464}{\text{Sn}} \right) 12.699$
400 F.	$\frac{d \text{Sn}_\Delta}{d t_\Delta} = .00638 \left(\frac{.0474}{\text{Sn}} \right) 6.463$
420 F.	$\frac{d \text{Sn}_\Delta}{d t_\Delta} = .00944 \left(\frac{.0483}{\text{Sn}} \right) 4.128$
440 F.	$\frac{d \text{Sn}_\Delta}{d t_\Delta} = .0126 \left(\frac{.0492}{\text{Sn}} \right) 2.906$

As only two alloy layers were employed a general expression for the rate of growth could not be obtained. The rate of growth for each alloy at each temperature had to be calculated separately. The rates of growth for each alloy at each temperature are shown in Tables 1 and 2.

Figures 7 and 8 show the change in the rate of

TABLE 3—Expected Free Tin Remaining on 0.250 Pound Electrolytic Tin Plate After Reheating. Untreated Plate with a 0.084 lb./BB Alloy Layer (Both Sides).

Time at Temperature	LB./BB OF FREE TIN			
	380 F	400 F	420 F	440 F
1 minute	.154	.149	.144	.140
2 minutes	.149	.139	.134	.125
4 minutes	.144	.132	.120	.105
8 minutes	.140	.124	.103	.080
16 minutes	.134	.110	.082	.047

growth as the alloy layer increases for each base alloy. The figures were obtained by substituting a value of the alloy layer (Sn) that might be present at any time (t_Δ) into the equations of Tables 1 and 2, respectively. The rate of growth decreases as the alloy layer increases, but at the same alloy content the growth rate for the low initial alloy is substantially below that of the high initial alloy.

Table 3 shows the expected amount of free tin remaining on 0.250 pound tin plate after various times at temperature. The table was calculated using the rate of growth equation for the heavy alloy series.

Discussion

The growth of the alloy is not a simple process as two intermetallic compounds are involved as shown in the phase diagram (Figure 9). When the plated tin is fused slightly above the melting point of tin (450 F), the alloy layer formed is almost entirely FeSn_2 with little or no trace of the second compound FeSn , according to Kunze and Willey,² Mantell,³ and others. At temperatures below 450 F

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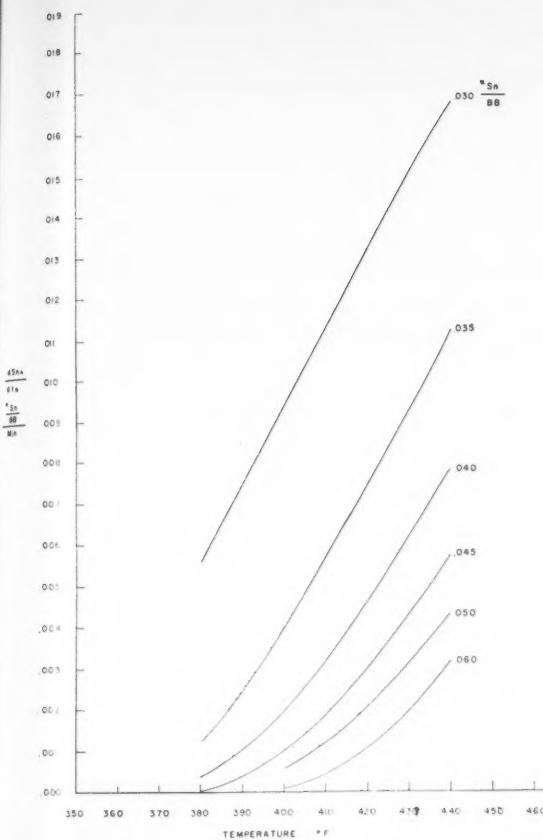


Figure 7—Rate of growth of low alloy plate.

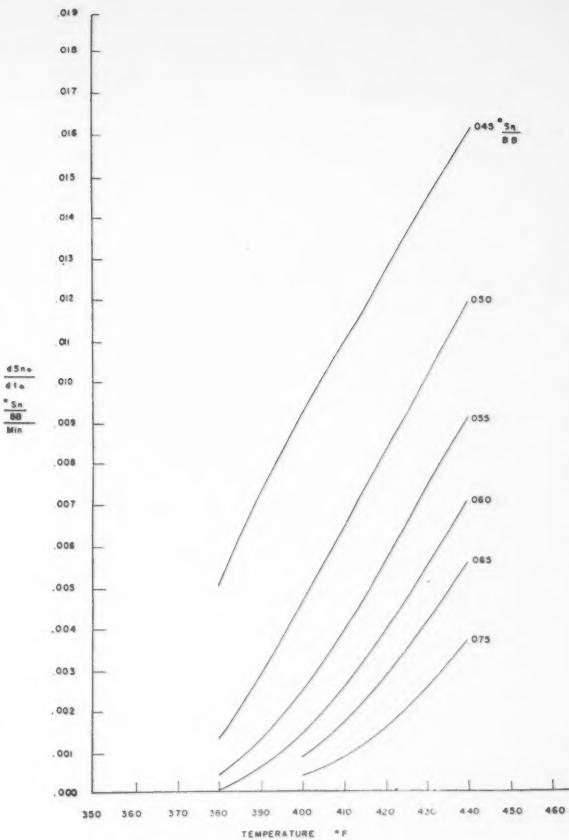


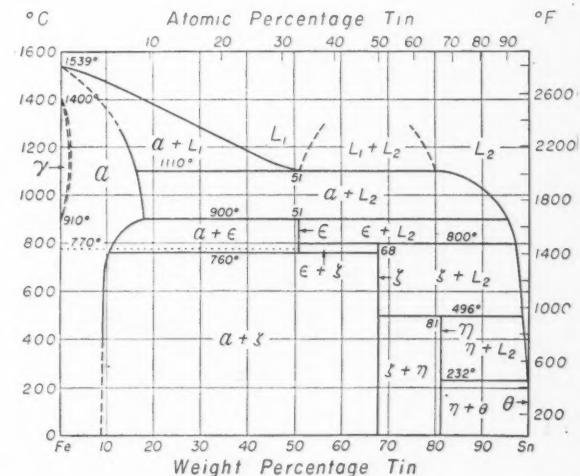
Figure 8—Rate of growth for high alloy plate.

the FeSn layer must start to grow by a diffusion process.

The initial rate of growth of the alloy layer after fusion will be approximately that of the FeSn₂ because the small amount of FeSn present has little influence on the diffusion rate. As the FeSn layer starts to grow, its influence increases as indicated by the change in the rate of growth of the alloy with increased alloy layer. The time at temperature and the amount of tin present were insufficient to determine if the rate of growth was proportional to the square root of the treating time which would suggest the growth rate to be a true diffusion phenomenon.

Analytical determinations for the exact amount of FeSn and FeSn₂ present in the alloy were unsuccessful because of the small amount of alloy present. The relative thickness of the tin coating on 0.25 pound tin plate⁴ is 1.5×10^{-5} inches or expressed in grams the amount of tin present is 2.9×10^{-4} grams per square centimeter. Only a portion of this is the total alloy which must be analyzed for the two compounds.

The results of the rate of growth curves indicate that while the amount of initial alloy formed on fusion is important, the temperature and time of baking of the enamel coating is also very important. Baking of enamel coatings should be performed at as low a temperature as possible even though the

Figure 9—Iron-tin equilibrium phase diagram.⁵

time may have to be increased slightly over that of a higher temperature. Table 3 indicates that if the temperature of baking is lowered 20 degrees F the time at temperature can be doubled with approximately the same amount of free tin remaining on the plate. The results of the slightly longer time at a lower temperature would be to have more free tin

available, regardless of the initial layer, thus giving better results in the manufacturing operations.

Summary

The growth of the alloy layer in quarter pound electrolytic tin plate at temperatures below the melting point of tin may be expressed by the equation:

$$Sn = a(t_s + b)^n$$

The values of the constant, a , and the exponent, n , were found to be linear with temperature over the temperature range studied.

The actual rate of growth of the alloy layer at the temperatures investigated may be expressed by the equation:

$$\frac{d Sn_A}{d t_s} = an \left(\frac{a}{Sn} \right)^{\frac{1-n}{n}}$$

However, a general expression for the rate of growth of the alloy layer for all base alloy layers could not be obtained as only two base alloy layers were employed.

The alloy growth process involves two intermetallic compounds, $FeSn_2$ and $FeSn$. Only the $FeSn_2$ is present after fusion, but both compounds must grow by a diffusion process at the baking temperatures. The rate of growth decreased as the alloy layer increased. There was insufficient time and tin layer

to determine if the rate of growth was proportional to the square root of the treating time.

In order to have the lowest alloy layer after baking, the baking temperature should be as low as possible even though the baking time would have to be increased slightly. A decrease of 20 degrees F allows doubling of the baking time for approximately the same amount of free tin available.

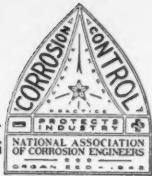
Acknowledgments

Acknowledgment is made to the Inland Steel Company for permission to publish these data; to J. W. Halley, Assistant Superintendent of Research and Development, for his helpful criticism throughout the course of this investigation; and to the members of the Research and Development Division for their assistance in carrying out the experiments.

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Any discussions of this article not published above will appear in the December, 1955 issue.



Technical Committee Activities

Current Status of Corrosion Mitigation Knowledge On Sweet Oil Wells*

A Report of Technical Unit Committee T-1C on Sweet Oil Well Corrosion*

Unit Committee T-1C is interested in high pressure sweet oil well corrosion and its control and has accumulated considerable data on both water-independent and water-dependent wells. This report is a summary of the problems involved and a discussion of some theoretical aspects and practical mitigation measures.

Water Independent Corrosion

IT APPEARS that corrosion in high pressure flowing wells which produce pipe-line oil has become almost commonplace in some areas. The problem was discovered in the Louisiana Gulf Coast area and it is in this area that the problem now is most prevalent. The problem also occurs in fields in the Eastern Gulf Coast of Texas and there is good reason to expect that several fields in Southwest Texas will experience corrosion of this type.

That considerable uncertainty as to proper mitigative measures is involved becomes obvious when operators attempt to specify methods of reducing corrosion damage in these wells. At present three methods are in use: Coated tubing, inhibitors and alloy tubing. Coated tubing apparently has found greatest favor and several operators believe it is the most economical and practical choice of the methods now available.

Epoxy Materials Tested

Until recently, baked-on phenolics have been used in almost all coating installations. Experimental installations of both air-dry and baked epoxy materials now are being reported for the first time. It is anticipated that a reasonably good idea of their merits will be available in two years.

Inhibitor Sticks Held on Bottom

The greatest obstacles to use of inhibitors in high pressure oil wells are mechanical. Conventional treating with liquid is, of course, out of the question and very little success has been obtained with dropping weighted sticks. Some operators have resorted to pushing sticks to bottom with wireline tools. A modification of this method uses a wireline tool

Abstract

Corrosion in high pressure flowing oil wells is becoming increasingly common. Methods currently used to limit corrosion damage include coated tubing, inhibitors and alloy tubing, with tubing coated with baked on phenolics being favored most. Epoxies are being tested as a tubing coating.

Lack of success with weighted inhibitor sticks is reported, but some operators are pushing sticks to bottoms with wire tools. Bottom hole injection is being tried by some, but because of gelling of diluents in wells with high bottom hole temperatures, caution in selecting diluents is advised. Results on use of alloy tubing are inconclusive.

Laboratory work on duplicating the conditions noted with respect to sparingly soluble sulfate scales has met with considerable success. A technique for preparing artificial scale is reported. A theory covering the reason for the porosity of the scale is advanced.

In connection with corrosion believed water dependent it is questioned whether circulation of a well after treatment down the annulus is beneficial. Some organic corrosion inhibitors are believed to accelerate corrosion at low concentrations.

A new task group organization has been made by the committee.

which holds the sticks on bottom until they dissolve.

Bottom Hole Injector Technique

Interest in bottom hole injector valves continues on the part of several operators. Both success and failure have been reported and it is generally agreed that the techniques of preparing the well and running the tool often determine the success or failure of the installation. It is mandatory that the casing be clean and that the hole be free of all debris. Elaborate circulating procedures have been followed in some cases to assure proper running-in conditions.

Another problem which has been encountered in using bottom hole injector valves is that of "coking" or gelling of inhibitor—crude mixtures injected into the annulus of wells having high bottom hole temperature. Caution in selecting the diluent is indicated and it is considered best to use the crude produced by the well being treated, if a crude must be used. The fact that some inhibitors apparently lose effectiveness at the higher bottom hole temperatures has been commented upon in previous reports.

Alloy Tubing Results Inconclusive

From the standpoint of field experience with alloy

*Presented at a meeting of T-1, Chicago, Ill., March 7, 1955.
*H. E. Greenwell, Atlantic Refining Co., Dallas, chairman.

tubing materials, little that is conclusive can be reported. Several strings of 9% nickel are known to be in use, but the committee does not have sufficient data at present to discuss the economics of using this material. One operator is using combination tubing strings consisting of 2000 feet of 9% nickel tubing at the top of the string, the balance being coated tubing. The purpose of the nickel tubing is to permit swabbing without damaging the protection.

Laboratory Work Reported

Considerable effort has been expended in studies of the mechanism of corrosion in recent years, since there are many aspects of the problem which are not understood. At the last meeting of the unit committee one company reported and discussed laboratory and theoretical work now in progress.

The work reported was concerned with the theory which has been proposed to describe the corrosion in terms of hydrolysis of sparingly soluble sulfate scales which have been found in many samples of corroded tubing. Results of rather extensive laboratory experiments were reported and some theoretical calculations based on this work were discussed. The report is summarized below:

The main characteristics of this type of corrosion are the deep pits found under scale. The pits are only partially visible before the scale is removed. This scale has been found to be a mixture of sparingly soluble sulfates and soluble hydroscopic salts. The pits are filled with scale and corrosion products which gives the scale a dull red color of honeycombed appearance. Concentration of hydroscopic salts (mostly sodium chloride) is higher in the pits than in the vicinity of the pits. The pH value of the scale varies from 5.5-7. Scale is an aggregate with pores. The pores are interconnected by small channels leading from the metal to the surface of the scale. Average tubing life in this type of corrosion is 3 to 4 years.

Since the amount of carbon dioxide in wells has been found to be under 0.1 percent, it was thought that factors other than carbon dioxide contributed to the tubing failures. It was believed that hydrolysis of sulfate scale may be the reason for corrosion.

Preliminary investigations were then started and results obtained from these experiments were encouraging.

Elaborate experiments were set up which encompassed various combinations of corrosive and hydroscopic salts. Scales were made up in various proportions of these constituents to bracket all natural compositions reported. Various alloys were included which made it possible to measure IPY values. Specimens were exposed to the corrosive action of the scales in a nitrogen atmosphere.

Material	Average MPY	Avg. Life in Years
N-80	84	2.5
J-55	84	3.1
9% Ni	48	4.5
9% Cr.	60	4.1
TK-2	15.5	12
	56	3.6*

* When a scratch (approximately 0.0-1/2-inch) was made prior to covering with scale.

The scale was obtained by precipitating CaCl_2 or BaCl_2 with H_2SO_4 . Precipitate was washed with water until a neutral pH value was obtained. (100 gm were washed with 4 gallons of water). After that, the constituents were mixed and the distilled water added (5 gm scale—2 ml water). The paste was then put on the half of each coupon and specimen stored in the inert atmosphere.

Scales originally were white but turned dark brown and the pH values of the scales changed as the experiment progressed. The pH value of the scales near the metal averaged 5.1 and the surface scale showed an average pH of 3.2.

Results obtained after nine months showed that attack experienced in wells apparently was reproduced under laboratory conditions. Pitting was observed in 99 percent of specimens exposed.

The average penetration rate and corresponding life were calculated from laboratory results as shown in Table 1.

Examinations of produced oil in Bayou Sale showed that emulsified water droplets contain nuclei of different salts. A much greater amount of salts is suspended in the oil. The salts are coated with wax which acts as an emulsifier. Because of turbulence in the tubing, the electrically charged particles grow in size, forming clusters. The particles increase in density and precipitate, forming a scale. Because of insufficient water for crystallization, growth of nuclei cannot occur so the scale grows by accumulation of the particles. Precipitation of shaped small particles accounts for the porous properties of scale.

Hygroscopic salts in the scale absorb water from oil which through hydrolysis of sulfates creates an acid pH.

The first corrosion product formed (FeSO_4) undergoes hydrolysis, forming an alkaline and an acid compound. Because the solubility and strength of the alkali and the acid differ, the acid and base interact with water to different extents, lowering the pH value further. The reaction metal—ferrous sulfate—ferrous hydroxide—precipitate appears to be continuous and seems to depend on water supply only. The limiting factors which determine the ultimate rate of corrosion have not been defined clearly.

Water Dependent Corrosion

Many of the immediate problems of water dependent corrosion are those concerned with field practices. Although several theoretical questions are yet unanswered, much can be gained by successful application of preventive methods which have been proved.

The overall problem of economical operation of fields producing large volumes of water is of vital concern to the corrosion engineer. In many cases, these operations are almost marginal and it is just as important to know when not to treat as when to treat. Often, rod and tubing failures can be controlled largely by employing good design methods. Lifting costs can be reduced considerably in some cases through a systematic program of remedial work to reduce water production. It is in fields of this type that the corrosion engineer must coordinate his work

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Benefits of Circulation Weighed

Mechanical problems of treating still occupy a substantial portion of the efforts being made to control water dependent corrosion. Experience of several committee members suggests that circulation of a well after treatment down the annulus may be of little long range benefit. It was pointed out that circulation when initiating a treatment is desirable both from the standpoint of establishing early inhibition and for obtaining early test results for evaluation. Otherwise, it appears that few benefits are realized from circulating. There are many fields in which down time circulating results in lost production and it is in these cases that this principle appears most important. There is sufficient experience with treating without circulation to assure that the chances of the procedure being successful in a given field are very good.

Some Organic Inhibitors Harmful

Experimental work concerned with the more fundamental aspects of inhibitors has demonstrated to one operator that some organic adsorptive inhibitors can accelerate corrosion at low concentrations. Tests run with various commercial materials showed that some produce an increase of pitting, while others do not. Present information was described as being quite qualitative with respect to field practice. No conclusions were drawn as to sensitive concentrations in actual wells. It is hoped that this matter will be pursued further in future committee work.

Coated Tubing Attractive

Coated tubing is being employed widely in fields having water dependent corrosion. The mechanical difficulties of treating many wells have made coated tubing especially attractive. Coated tubing has become the standing field-wide recommendation in several cases reported. As in the case of corrosion in

high pressure wells, baked-on phenolics constitute the bulk of installations in service, but several operators now are experimenting with epoxy materials.

Several operators have experienced acceleration of corrosion in the tracks left by caliper tools. This effect has occurred in both types of sweet oil well corrosion. One step taken to prevent this effect is slug treatment with inhibitor immediately after running the caliper. This problem is considered quite serious in some cases and special caution is indicated when caliperizing wells which are not ordinarily treated.

Task Groups Formed

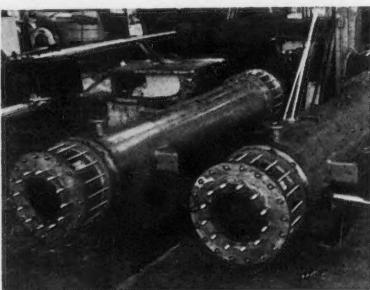
As a result of the many new facts reported at a recent meeting, it was decided that the committee could profitably sponsor new surveys of industry practice and experimental work. Since the interest of the committee are rather diverse, it was decided to conduct future work through task groups which can maintain more specialized interest. Objectives of the committee were classified into four parts, and task group leaders were selected as follows:

1. Water Dependent Corrosion
 - A. Field Practices—Joy T. Payton, The Texas Co., Houston.
 - B. Experimental Aspects—John A. Rowe, Jr., Gulf Oil Corp., Houston.
2. Water Independent Corrosion
 - A. Field Practices—Howard E. Greenwell, Atlantic Refining Co., Dallas.
 - B. Experimental Aspects—Rado Loncaric, Atlantic Refining Co., Dallas.

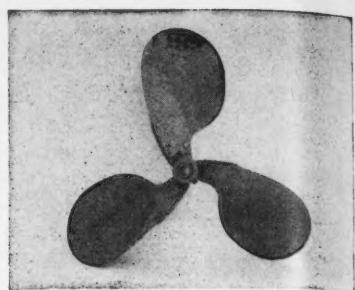
These task groups will be responsible for determining the current status of the industry with respect to their respective assigned fields and for coordinating committee work. It is anticipated that detailed surveys will be made in the next few months to bring T-1 up-to-date on new problems and current field practices.



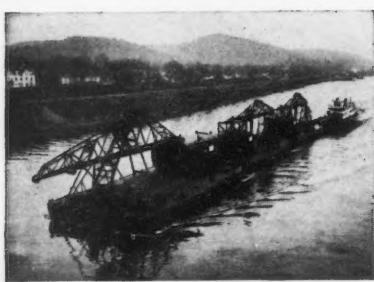
Pipe Lines



Heat Exchanger



Domestic Appliances



Ships and Barges



Drainage Structures



Farm Equipment



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*Corrosion***

**seeking answers to
their problems!**

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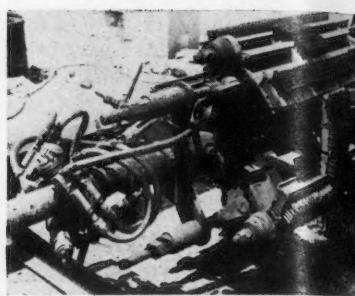
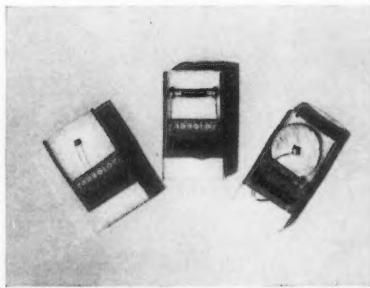
- If your company is seriously interested in selling to corrosion engineers, this monthly official publication of the National Association of Corrosion Engineers is a good place to advertise. Pre-selected prospects already interested in corrosion-control will see your message.

- And all this at very modest rates. A full page advertisement costs a fraction more than 4c a paid reader. It is hard to find a better, more economical or more effective way to reach the men who do the corrosion control work.

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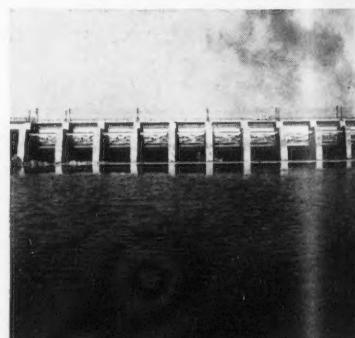
Packaging



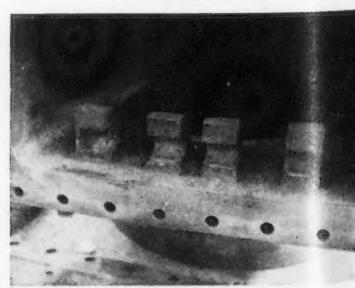
Painting Equipment



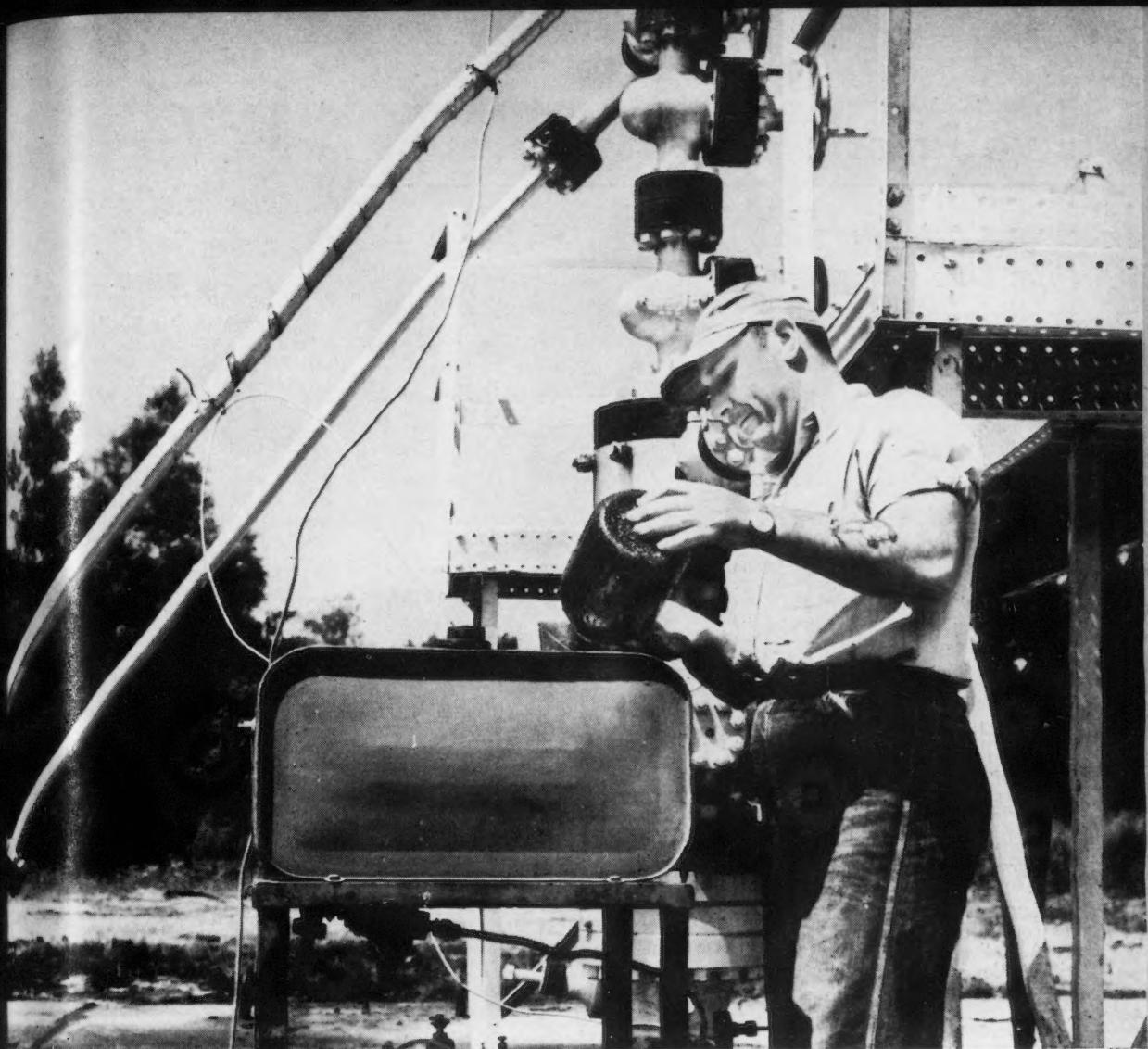
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services for the oil industry



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Five Plastic Film Task Groups Are Organized

Organization of Gas Pipe Line Committee Is Weighed by T-2

W. H. Stewart, Sun Pipe Line Company, Beaumont, Texas, chairman of Technical Group Committee T-2 on Pipe Lines, has announced that efforts are being made to form a new unit committee under T-2. The new unit committee will be called Gas Pipe Line Corrosion Problems. A. L. Stegner, Tennessee Gas Transmission Company, has accepted the temporary chairmanship to organize the committee. Mr. Stegner said that activities of the committee will be directed toward problems peculiar to the gas pipe line industry, both in the transmission and distribution field. He indicated that probably the first task group to be formed will be a task group assigned to study the problem of corrosion at compression stations.

Mr. Stegner plans to enlist members for the gas pipe line committee from the various gas transmission and distribution companies and has emphasized that he is looking for engineers from all phases of corrosion work in the gas industry. He is especially interested in the younger engineer becoming active in the committee and hopes that he will be successful in securing members among field personnel as well as corrosion engineers engaged in laboratory and office work.

NACE members interested in joining this committee are encouraged to contact A. L. Stegner, Tennessee Gas Transmission Company, Box 2511, Houston, Texas.

T-2C Plans Meetings At Houston, Niagara Falls

L. P. Sudrabin, Electro Rust-Proofing Corp., Newark, New Jersey, chairman of Unit Committee T-2C on Minimum Current Requirements for Cathodic Protection, has announced that in addition to the meeting of T-2C scheduled during the South Central Region Meeting in Houston during October, the committee will hold a meeting during the Northeast Region Meeting in Niagara Falls, New York, November 1.

In scheduling the two meetings so close together, Mr. Sudrabin hopes to enable all members of the committee to attend this important meeting of T-2C. Those in the North and Eastern Section of the United States who cannot attend the South Central Region session will have an opportunity to attend the Northeast Region meeting and vice-versa.

Mr. Sudrabin has asked members of the committee to be prepared to discuss views on specifications on measuring the minimum current requirements for the cathodic protection of buried pipe lines. He also hopes the committee will be able to establish the present feeling on the environmental factors which influence minimum protection requirements at these two meetings of Unit Committee T-2C.

All members of the committee are urged to be present.

TENTATIVE SCHEDULE SOUTH CENTRAL REGIONAL MEETING

Houston, Texas, October 18, 19, 20, 21, 1955
Committee

- T-1 Corrosion in Oil and Gas Well Equipment. All Day Tuesday
- T-1C Sweet Oil Well Corrosion. 1:30 P.M. Wednesday
- T-1D Sour Oil Well Corrosion. 8:30 A.M. Wednesday
- T-1D-1 Fundamentals of Corrosion. 9:00 A.M. Thursday
- T-1G Sulfide Stress Corrosion Cracking. 9:00 A.M. Friday
- T-1H Oil String Casing Corrosion. 10:00 A.M. Wednesday
- T-1J Oil Field Structural Plastics. 9:00 A.M. Thursday
- T-1K Inhibitors for Oil and Gas Wells. 1:30 P.M. Wednesday
- T-2A-2 Ribbon Anodes. 9:00 A.M. Tuesday
- T-2B Anodes for Impressed Currents. 1:30 P.M. Tuesday
- T-2C Minimum Current Requirements for Cathodic Protection. 9:00 A.M. Wednesday
- T-2D Standardization of Procedures for Measuring Pipe Coating Leakage Conductance. 1:30 P.M. Wednesday
- T-2E Internal Corrosion of Product Pipe Lines and Tanks. 9:00 A.M. Wednesday
- T-2K Prefabricated Plastic Film for Pipe Line Coating. 1:30 P.M. Wednesday
- T-3B Corrosion Products. 1:30 P.M. Tuesday
- T-4F-1 Water Meter Corrosion. 1:30 P.M. Tuesday
- T-5B-2 Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry. 9:00 A.M. Wednesday
- T-5C-1 Corrosion by Cooling Waters, South Central Region. 1:30 P.M. Wednesday
- T-5E Stress Corrosion Cracking of Martensitic Stainless Steels. 1:30 P.M. Tuesday
- T-6A Organic Coatings and Linings for Resistance to Chemical Corrosion. 9:00 A.M. Tuesday
- T-6B Protective Coatings for Resistance to Atmospheric Corrosion. 9:00 A.M. Wednesday
- T-6E Protective Coatings in Petroleum Production. 9:00 A.M. Thursday
- Corrosion Coordinating Committee, South Central Region, 4:00 P.M. Thursday.

Characteristics of Pressure Sensitive Tapes to Be Probed

F. E. Costanzo, Manufacturers Light & Heat Co., Pittsburgh, Pennsylvania, chairman of Technical Unit Committee T-2K on Prefabricated Plastic Film for Pipe Line Coatings, has announced the organization of five task groups. The task group chairmen and assignments are as follows:

T-2K-1, History and Results—H. D. Segool, Polyken Products, Chicago, Illinois, is chairman of this task group, whose assignment is to prepare a history of experience on the use of prefabricated plastic films such as pressure sensitive tapes with experience and results obtained.

T-2K-2, Physical Characteristics—H. M. McDaniel, Republic Steel Corp., Cleveland, Ohio, chairman. This group's assignment is to study bonding agents or adhesives including the proper application to the pipe where an adhesive or catalyzed bonding agent is applied to pipe and a plastic film is applied separately. To study the water solubility, osmosis created by cathodic protection, oil and hydrocarbon solubility of bonding agents, chemical resistance, etc.

T-2K-3, Research and Development—A. C. Kilberg, Minnesota Mining & Manufacturing Co., St. Paul, Minnesota chairman. This task group's assignment is to study prefabricated plastic films available now and as they are discovered in the laboratory, paying particular attention to the plasticizers used to eliminate the possibility of a cheap plasticizer causing a breakdown of an otherwise good film with recommendation to both the manufacturers and corrosion engineers. To study the moisture vapor transmission and chemical resistance, etc. of plastic films.

T-2K-4, Application—R. B. Bender, Plastic Engineering & Sales Corp., Fort Worth, Texas, chairman. This task group's assignment is to study the proper application of both pressure sensitive tapes and prefabricated films as applied to pipelines, specifically as pipeline coatings with recommendations for proper use.

T-2K-5, Standard—C. A. Bailey, Johns-Manville Sales Corp., New York, New York, chairman. This task group's assignment is to study the characteristics of plastic pressure sensitive films used for pipe protection and to establish standard methods for the measurement of the characteristics.

Mr. Costanzo has also said he has appointed a nominating committee to nominate candidates for the office of vice-chairman of T-2K. A letter ballot for the office of vice-chairman will be held immediately following the report of the nominating committee.

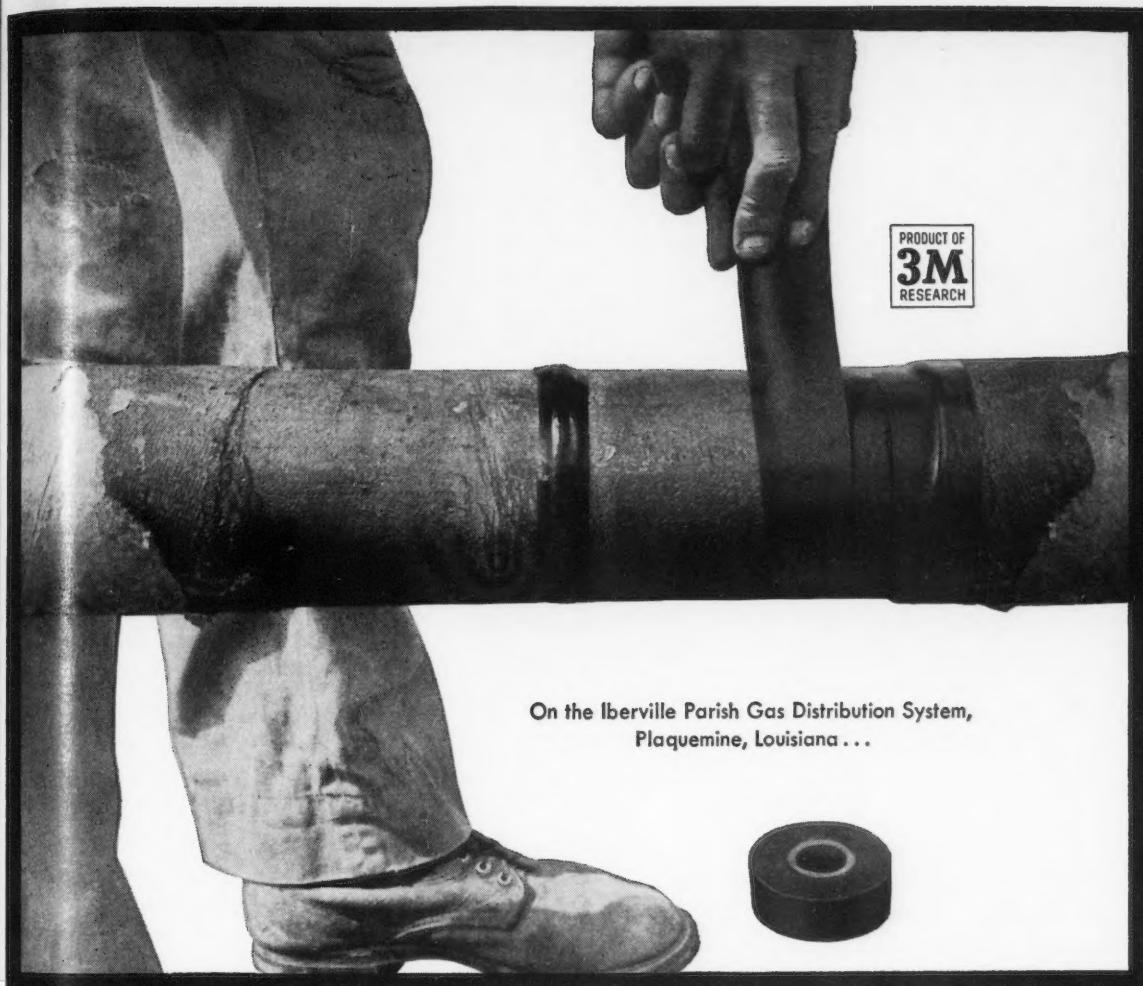
Currently, the committee has eighteen members. These members are affiliated with major plastic adhesive producers, applicators, a plastic coated pipe manufacturer and users. The chairman, Mr. Costanzo, has advised the task group chairmen they should start gathering information and coordinating objectives with their committees as soon as possible.

(Continued on Page 68)

More than 1400 copies of Corrosion are mailed monthly to addresses outside the United States.

Five Technical Committee reports have been published in 1955 by NACE through June.

October, 1955



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**Henke Is Now Chairman
Of Utilities Industry
Materials Selection Unit**

R. W. Henke, Badger Meter Manufacturing Company, Milwaukee, Wisconsin, has been appointed chairman of NACE Technical Unit Committee T-4F on Materials Selection for Corrosion Mitigation in the Utility Industry. F. E. Kulman, Consolidated Edison Company of New York, Inc., chairman of Technical Group Committee T-4, announced the appointment and at the same time, announced that R. R. Ashline, Department of Water and Power, City of Los Angeles, has resigned as chairman of the committee.

Mr. Henke is currently Chief Mechanical Engineer, Research and Development Division of the Badger Meter Manufacturing Company. He formerly was project engineer with the Heil Company. He received a BS and MS in mechanical engineering from the University of Wisconsin and is a registered professional engineer in Wisconsin. He is a member of NACE, ASM, ISM and ASTM. He is a member of the ASTM Committee on hard rubber material. Mr. Henke is the author of several papers on meters and chemical proportioners and recently received the 1954 Gray Iron Founders Society's Award of Redesign.

Currently, Mr. Henke is chairman of NACE Task Group T-4F-1 on Water Meter Corrosion. However, he advises since he will take over the chairmanship of Unit Committee T-4F, he hopes to appoint a new chairman for the task group.

**South Central Corrosion
Coordinating Unit Set**

An effort will be made to organize a new technical unit committee to be called Corrosion Coordinating Committee, South Central Region, during the South Central Region meeting scheduled for October 18-21 at the Shamrock-Hilton Hotel in Houston, Texas.

A meeting will be held in the Castilian Room of the Shamrock beginning at 4 p.m. Thursday, October 20 to discuss the organization of the new committee. NACE members interested in organizing such a committee are urged to be present. Anyone interested in learning of the proposed activities of the committee should contact C. L. Mercer, Engineering Department, Southwestern Bell Telephone Company, Box 58, Westfield, Texas. Mr. Mercer is one of a group interested in forming the committee and will act as chairman at the October 20 meeting.

Five Plastic Film—

(Continued From Page 66)

sible and believes the committee has an excellent cross section of personnel with much information already available.

Technical Unit Committee T-2K will hold its second meeting during the South Central Region Meeting in Houston, Texas. The meeting is scheduled to begin at 2 pm Wednesday, October 19, in the Normandy Room A of the Shamrock-Hilton Hotel in Houston.

Corrosion is available on a subscription basis to non-members of NACE.

A N E D I T O R I A L

What You Should Know About the NACE Technical Committees

The Technical Practices Committees of the National Association Corrosion Engineers were organized about ten years ago. They grew out of an earlier technical committee set up to study condensate well corrosion which later became Technical Practices Committee No. 1. Through 1953 the number of committees had grown to 19. To provide for adequate control and delegate responsibility the committees were reorganized effective March 18, 1954. At the same time a Technical Committee Operation Manual for the guidance of technical committee activities was put into effect. This article is a brief explanation of the functions of the existing various committee categories.

Technical Practices Committee

The Technical Practices Committee is a policy making group composed of a chairman, vice-chairman, vice president of NACE and the chairmen of the six Technical Group committees. The president of NACE and the executive secretary of NACE are members ex-officio. This committee coordinates activities and functions of all the technical committees and acts on policy and planning matters affecting them. It is responsible to the association's board of directors through its chairman.

Managing Committee

The chairman and vice-chairman of the Technical Practices Committee, with the vice president of NACE constitute the Managing Committee. This committee acts for the Technical Practices Committee subject to approval at a later meeting of the latter.

Technical Group Committees

When the Technical Practices Committees were reorganized in 1954, the existing technical committees were re-grouped according to industry. For example all groups working on corrosion problems in oil and gas production were grouped into a committee called Corrosion in Oil and Gas Well Equipment; all working on corrosion problems of pipe lines were grouped into a committee called Pipe Line Corrosion. To ensure that responsibility is properly delegated and to provide a policy and planning group for each industry, it was decided to establish the Technical Group Committees. These are T-1, T-2, T-3, T-4, T-5 and T-6. These industry Group Committees are policy and planning committees. They function in their respective industry classifications in the same way that the Technical Practices Committee functions with respect to the overall committee organization. Group Committees consist of a chairman, vice-chairman and the chairmen of all the Unit Committees under the industry group classification. These committees work on management and not on technical problems. Chairmen of the Group Committees are appointed by the chairman of the Technical Practices Committee. Group committee vice-chairmen are elected by the group committee.

Technical Unit Committees

The technical unit committees are the working committees of the association. These are numbered to indicate the industry group, and have a letter designation also. Unit committees work on corrosion problems within their authorized scopes. The scope may be broad or narrow to fit the problem at hand.

For instance, the scope of the Unit Committee T-2H, Asphalt Type Pipe Coatings, is "To set up specifications for the application and use of asphalt type underground protective coating systems," and the scope for Unit Committee T-3A, Corrosion Inhibitors, is "To obtain and to make available information on corrosion inhibitors, to promote the proper use of inhibitors, to promulgate practices for evaluation of corrosion inhibitors and to encourage research on inhibitors." The objects of T-2H are relatively specific, while those of T-3A are general.

Unit Committees are urged to hold meetings at least twice each year with one meeting at the NACE annual conference. At these meetings, project reports are given, reports are discussed, new problems brought up, and general committee work carried on. Meetings usually are well attended by both members and guests.

New Unit Committees are formed when some definite activity is proposed and urged by a group of NACE members interested in a problem or subject. They are terminated when the project is completed or when lack of activity and interest is evident. Currently there are some 45 unit committees actively working on corrosion problems. Three new units are in the formation stage. Any member of NACE is eligible to become a member of any technical unit committee. Members interested in joining any unit committee need only to write chairman of the committee stating their interest and willingness to participate in the committee activities. Membership in more than one committee is common and in most cases, very beneficial to the committee and the individual. All NACE members who are not now members of one or more technical committees are urged to study the scopes published in the Technical Committee Directory portion of the 1955 NACE Yearbook and apply for membership in those of interest. Committee membership is not limited to those with long years of experience in corrosion or to research workers. Any NACE member working in corrosion, in the field, the laboratory, or wherever his duties may be is invited to join and participate in the work of the committees.

Task Groups

Specific work assignments are often accomplished by appointed task groups. These groups are appointed by the chairman of the unit committee setting up the task group. Task groups may be set up and terminated at the will of the unit committee. A member of a task group is automatically a member of the unit committee under which the task group operates. Generally the work assignment of a task group is specific and in many instances scheduled for completion by a set date. In other cases, task groups work on problems more general in nature and may be active for several years. If a NACE member desires to join a task group, he should apply in writing to the chairman of the unit committee under which the task group is formed.

In general, technical committees of the association are very active. Many unit committees and task groups are working on technical reports, recommended practices and in some cases, suggested standards. The work of the technical committees is vital to the welfare of NACE and each member should contribute to the committee activity as far as possible.

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NACE News

Busy Fall in Prospect for Association Members

Five Symposia Scheduled for November 10-11 Southeast Region Meeting at Miami, Fla.

Five symposia are planned for a November 10-11 meeting of Southeast Region at Key-Biscayne Hotel, Miami. Twelve items are included in the tentative program issued by Joseph Frink, Florida Power and Light Co., Miami. The tentative program is as follows:

Thursday, November 10

Atomic Energy Symposium

Reactor Development—Speaker to be named.

Light Energy Batteries—Speaker to be named from New York Bell Telephone Company laboratories.

Process Industries Symposium

Aluminum—Edward T. Wanderer of Aluminum Company of America, New Kensington, Pa.

Stainless Steel—John M. Perryman of R. D. Cole Co.

Condenser Tubes—Speaker to be named.

Marine Corrosion Symposium

Atmospheric—T. P. May, The International Nickel Co., Inc., New York.

Tidewater—F. L. LaQue, T. P. May, The International Nickel Co.

Underwater—Walton Smith, University of Miami.

Friday, November 11

Protective Coatings Symposium

Surface Preparation—Arno J. Liebman, Pitmar Centrifugal Machine Corp., Baltimore.

New Developments, Evaluation and Inspection (subject to change) J. G. Lacy, Amercoat Corp., South Gate, Cal.

Cathodic Protection Symposium

Underground and Marine—Speaker to be named.

Cathodic Protection—M. C. Miller, Ebasco Services, Inc., N. Y.

A panel discussion will be held as the last event of the technical program Friday. H. C. Van Nouhuys, Southeastern Pipe Line Company, Atlanta, will be moderator. Members of the panel will be the speakers at symposia. Also Friday afternoon a series of motion pictures concerning corrosion will be shown. A display of corrosion control instruments from major companies will be held.

A banquet will be held Friday night with orchestra.

Business meetings of the Jacksonville and Miami Sections will be held during the regional session.

Four Bibliographic Surveys of Corrosion have been published by NACE covering literature published in the years 1945-51 inclusive.



NACE MEETINGS CALENDAR

Oct.

- 31 Vancouver Section, R. B. Seymour, "Plastics for Corrosion Resistant Applications."
- 6 Pittsburgh Section, Mellon Institute, Oakland, Pa.
- 11 Cleveland Section, Corrosion of Internal Combustion Engines.
- 14 Philadelphia Section, Poor Richard Club, Round Table panel.
- 18 Chicago Section, Development of Galvomag Anodes and Their Uses.
- 18 Genesee Valley Section, German Club, Round Table discussion on architectural uses of aluminum.
- 24 Tulsa Section, Surface Potentials.
- 27 Sabine - Neches Section, Orange, Texas, External and Internal Corrosion of Storage Tanks.

Nov.

- 3 Pittsburgh Section, Mellon Institute.
- 7 North Texas Section, Dallas. Wrought Iron Corrosion.
- 8 Cleveland Section, Case History of Cathodic Protection Installation, Bernard Husock.
- 14 Genesee Valley Section, Joint meeting with American Society of Metals.
- 15 Chicago Section, Engineers' Club, Corrosion and Design, C. G. Munger.
- 28 Tulsa Section, Corrosion Clinic covering coatings, rectifiers, inhibitors, galvanic anodes.
- (Late) Carolinas Section.

Hackerman Is Selected

Dr. Norman Hackerman, Delegate Member Representative of the American Chemical Society to the Inter-Society Corrosion Committee has been elected vice-chairman to fill the unexpired term of Dr. N. E. Berry when it became necessary for Dr. Berry to resign.

ERRATA

1955 NACE YEARBOOK

Persons who have the NACE 1955 Yearbook may wish to add the following name to the list of corporate members on Page 49. The name was omitted in error.

The Duriron Company,
Dayton, Ohio. G. A. Baker

Seven Major Events Scheduled In Less Than Three Months

A busy fall is in prospect for members of the National Association of Corrosion engineers and many others who attend NACE meetings. Four regional meetings, two short courses and the Sixth Biennial Permian Basin Corrosion Tour will be held during October, November and December. Numerous section meetings also will be held from coast to coast.

Events of greater than local importance include:

- Oct. 11-14—Sixth Biennial Permian Basin Corrosion Tour.
- Oct. 18-21—South Central Region 1955 Annual Meeting.
- Oct. 31-Nov. 3—Northeast Region 1955 Fall Meeting.
- Nov. 10-11—Southeast Region 1955 Fall Meeting.
- Nov. 14-16—University of California Corrosion Short Course at Berkeley.
- Nov. 17-18—Western Region 1955 Fall Meeting.
- Dec. 5-9—University of Illinois Short Course on Corrosion.

Arrangements Completed For San Francisco Meeting

Arrangements have been completed for the November 17-18 meeting of Western Region at Sir Francis Drake Hotel, San Francisco. The meeting follows immediately the University of California's 3-day short course at Berkeley.

The technical program for the regional meeting features symposia on pipeline protection, oil well corrosion and corrosion of ocean-going vessels.

A banquet will be held Thursday night.

Permian Basin Corrosion Tour Opens October 10

The 4-day Sixth Biennial Permian Basin Corrosion Tour opens October 11 at the Lincoln Hotel, Odessa. The featured program includes inspection of about 300 pieces of equipment in 60 exhibits.

Registrants will visit exhibits in air conditioned busses and will cover a 3000-mile area in the Permian Basin region. Daily discussion sessions will be held.

Joseph E. Rench, Napko Paint and Varnish Co., Houston will speak October 12 on "What Paint Ain't." Charles W. "Chuck" Elwell, The Western Company, will speak October 13 on "Corrosion Engineers or Corroded Engineers."

Other stories on this tour were published in CORROSION's July issue, Page 66; August issue, Page 70 and September issue, Page 80.



Aker



Beggs



Erickson



Finnegan



Gates



Ingham



Kennedy



May



Mason



Parker



Pike



Shideler



Sinclair



Tracy



Plym



Werner

AUTHORS of papers to be given at Northeast Region fall meeting at Niagara Falls.

Nineteen Papers Scheduled For Niagara Falls Sessions

The 4-day Fall 1955 meeting of Northeast Region opens October 31 in Niagara Falls. J. M. Fouts, New York Telephone Co., Buffalo, general chairman, reports the program complete with 19 papers. Meetings of technical committees are scheduled for October 31. All sessions will be held at Hotel Niagara, Niagara Falls, N. Y. Niagara Frontier Section is co-sponsor of the meeting.

E. F. Dunn, Whitehead Metal Products, Inc., Buffalo, is chairman of the arrangements committee.



Dunn



Fouts

Northeast Region's Oct. 31-Nov. 3 Meeting Features 16 Experienced Corrosion Workers

Following are titles of technical papers to be given during the October 31-November 3 Northeast Region meeting at Niagara Falls and short biographies of authors.

Fundamentals of Corrosion by Thomas P. May, the International Nickel Co., Inc., New York. Dr. May is presently chairman of the NACE Publication Committee and has been active as an officer and on both standing and technical committees for many years. He is a member of the Development and Research Division of The International Nickel Co., Inc., N. Y. and holds a PhD in Physical chemistry. Formerly head of the Corrosion Section on the Research Staff, Chemistry Division, Naval Research Laboratory, he has been active in corrosion research since 1940. He is the author of many technical papers, and frequently lectures at corrosion short courses. He is a member of ACS, ASM and The Electrochemical Society.

Fundamentals of Corrosion Testing UnderGround Plant by Vernon B. Pike, Bell Telephone Laboratories, Murray Hill, N. J. Mr. Pike, who has been occupied with outside plant engineering with Bell Telephone Co., of Pennsylvania, American Telephone and Telegraph Co., Bell Telephone Laboratories,

Inc., since 1916 following service in the Air Corps in World War I, is an electrical engineering graduate of Lehigh University. He has been with Bell Laboratories since 1927 and has specialized on corrosion problems since 1950.

Earth Potential or Surface Potential Gradient Tests on Buried Telephone Cables by Daniel R. Werner, American Telephone and Telegraph Co., Kansas City, Mo. He has been in electrolysis work on telephone cables since 1934. He holds BS and EE degrees from Rose Polytechnic Institute, Terre Haute, Ind. Mr. Werner is now in charge of cable corrosion control engineering, Western Area for his company.

Corrosion Control Practices for Pipe-Type Cables on the Detroit Edison System by W. A. Sinclair, Detroit Edison Co., Detroit, Mich. He is supervising engineer of cable performance on the electrical system of his company. He has a BSEE from Wayne University, 1945 and besides NACE is a member of AIEE and the Engineering Society of Detroit.

Protection of Gas Distribution Mains and Services from Corrosion by Charles W. Beggs, Public Service Electric and

(Continued on Page 73)

The program scheduled is as follows: Tuesday, November 1—Fundamentals of Corrosion, Testing and Control Measures on Buried Telephone Cables and Pipe Type Cables; Niagara Frontier Section business meeting and election of officers.

Wednesday, November 2—Protection of Gas Service Lines, Wax Type and Coal Tar Pipe Coatings. Panel on Corrosion Problems in Steam Generating Stations and Pipe Line Compressor Stations, Fellowship Hour, banquet.

Tuesday, November 3—Cathodic Protection Problems, Organization and Ex-

(Continued on Page 74)

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Northeast Region's-

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Gas Co., Newark, N. J. Now Project Engineer—Gas Department, for his company, Mr. Beggs during 30 years has served in various capacities. Formerly chairman of the Corrosion Committee of the American Gas Association, he is a 1925 chemical engineering graduate of Lehigh University. He also is a member of NACE, New Jersey Society of Professional Engineers, ACS and other organizations.

The Use of Combined Plastic Film and Microcrystalline Wax for Protecting Underground Pipe from Corrosion by Ted Kennedy, Jr., sales Engineer, The Trenton Corp., Ann Arbor, Mich. After graduating from University of Michigan with a BS in aeronautical engineering in 1942 he was employed successively by Pratt & Whitney Aircraft Co., served as a naval officer in World War II, and after receiving a MBA from Harvard Graduate School of Business Administration became assistant to the vice-president and general manager of Dodge Division of Chrysler Corp. He joined The Trenton Corp., in 1954. He is a member of NACE and Tau Beta Pi.

Coal Tar Coatings for Protection of Underground Structures by Norman T. Shideler, Pittsburgh Coke & Chemical Co., Pittsburgh, Pa. Mr. Shideler is manager of the Protective Coatings Division of his company. He has a BA degree in chemistry from Indiana University, 1926. During his 17 years handling of the development, production and sale of coal tar coatings, Mr. Shideler spent six years in the research laboratories of Reilly Tar & Chemical Corp., was associated with the Wailes-Dove-Hermiston Corp., (later the Koppers Company) and joined his present company in 1948, starting its production of coal tar coatings.

Problems of Corrosion in Large Steam Generating Stations by Thomas J. Finnegan, Niagara Mohawk Power Corp., Buffalo, N. Y. A chemical engineer with Niagara Mohawk Power Corp., he is author of numerous papers on water conditioning, corrosion and related matters. Educated at the Polytechnic Institute of Brooklyn, he has been at various times Chemist in Charge, New York Steam Corp.; Research Associate, Consolidated Edison Co., of N. Y., Inc., and chemical engineer for affiliated companies which later formed the Niagara Mohawk system. He is a member of ACS, Fellow of the American Institute of Chemists; a member of ASME, Society of Professional Engineers and was chairman of the Edison Electric Institute Chemistry Committee, 1950-53.

Application of Copper Alloy Condenser Tubes and Corrosion Problems in Power Stations and the Petroleum Industry by A. W. Tracy, American Brass Co., Waterbury, Conn. Mr. Tracy, a metallurgical engineer for his company currently is chairman of the Editorial Review Subcommittee of the National Association of Corrosion Engineers. He attended Wesleyan University, Middletown, Conn., and has been in his company's Corrosion Research Laboratory since 1923. He is a member of AIMME,

ASTM, AES and is past chairman of Southern New England Section NACE.

Application of Corrosion Resistant High-Nickel Alloys in Steam Generating Stations and Pipe Line Compressor Stations by J. F. Mason, Jr., The International Nickel Co., Inc., New York City. Mr. Mason, who joined Inco in 1937, has been a member of its Corrosion Engineering Section for the past 17 years. His activities have been solely in fields involving corrosion resistant materials used in petroleum refining, soap and fatty acid production, power, marine, food processing and handling, pulp and paper, pharmaceutical production, leather tanning, textile processing and dyeing, coke by-product and general chemical production. He is a graduate of Manhattan College, New York

City 1933 with a BS in chemistry. He also attended Brooklyn Polytechnic Institute for two years in its chemical engineering school.

Sprayed Metal as a Base for Paint by Herbert S. Ingham, Metallizing Engineering Co., Inc., Westbury, N. Y. Mr. Ingham has been vice-president of his company for the past 18 years. A graduate of California Institute of Technology, his early experience was in design and manufacture of miscellaneous machinery, including electric motors and power transmissions at Sterling Motors, Inc., and metering equipment at Robinson Orifice Fitting Co., Inc., both in Los Angeles.

(Continued on Page 74)

These 4 great, new Anti-Corrosion products lead the league!

1 PRUFCOAT New "A" Hot-Spray Vinyl Gives Greater Mil Thickness, Improved Film Density, Better Adhesion — at Lower Cost!

Now, performance-proven Prufcoat "A" Series Vinyl has been adapted and specifically engineered for the modern, cost-saving technique of hot-spray. Prufcoat "A" Hot-Spray gives you greater mil thickness (4-5 mils in a single spray pass), improved film density (no porosity or pinholing) and better adhesion (to primers and even bare metal) at lower cost per sq. ft. of surface.

2 New! PRUFCOAT Odorless Chemical-Resistant Coatings Eliminate Chemical-Resistant Painting Odor Problems

Prufcoat Odorless Chemical-Resistant Coatings provide high resistance to acids, alkalies, and other chemicals. Scrubbable 24 hours after application, they withstand extensive scouring and cleaning. Ideal for use in confined, poorly ventilated areas. Suitable for application over wood, metal, or concrete. No wrinkling or lifting of old paints. Easy to apply, and supplied in a variety of colors.

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prime coat alone. Minimum surface preparation needed, yet there is positive adhesion and underfilm corrosion control.

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Tour of Niagara Falls Area

Is Scheduled for Ladies

A sightseeing tour of the Canadian and American Falls areas has been arranged for ladies accompanying persons attending the Northeast Region's fall meeting at Niagara Falls, October 31-November 3. Included also will be other points of major interest and luncheon in the Rainbow Room of Hotel Brock-Sheraton in Niagara Falls, Ont. From this glass-enclosed room both the Canadian and American falls can be seen. Busses will leave Hotel Niagara at 11:30

am and return about 5 pm Wednesday, November 2.

Through the courtesy of the Hotel Niagara and the City of Niagara Falls Convention and Visitors' Service a lounge suite will be available for rest and recreation.

Ladies registering for the conference also are invited to attend the Fellowship Hour and banquet Wednesday.

POSITIONS WANTED and AVAILABLE

- Active and Junior NACE members and Companies seeking employees may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point text type.
- Advertisements to other specifications will be charged for at \$10 a column inch.

Positions Available

Engineer—Corrosion: Excellent opportunity with a major oil company located in the Central States for a man who has had prior experience in cathodic protection work on bare and coated pipe lines. CORROSION, Box 55-26.

Graduate Electrical Engineer, experienced in maintenance of electrical controls for pipe line pumping equipment and the design and installation of cathodic protection systems for pipe lines. Travel required. Write P. O. Box 22, Harrisburg, Pa.

PLANT EQUIPMENT INSPECTORS

Senior Inspectors for Company operations in Saudi Arabia and Company Engineering Department in The Hague, Holland.

Should be graduate engineers with minimum eight years experience in design or inspection of petroleum processing plants and equipment. Five years actual inspection experience necessary.

In Saudi Arabia will advise operating departments on code and equipment limitations, develop inspection methods, supervise and conduct inspections.

In The Hague will inspect and approve equipment and material purchases, advise and assist foreign manufacturers to comply with United States standards and specifications. Salary commensurate with experience and training.

Write giving full particulars and work experience either directly to the Recruiting Supervisor, Arabian American Oil Company, 505 Park Avenue, New York 22, New York or to CORROSION, Box 55-27.

Positions Wanted

Corrosion Engineer—B.S. in Chemistry, age 28, married, 6 years varied chemical and corrosion engineering experience. Now employed in petroleum production corrosion engineering—research, development and application. Seeking greater job responsibilities and future opportunity. CORROSION, Box 55-25.

Power Company Official To Make Banquet Address

Rob Roy Macleod, Commercial Vice-President, Niagara Mohawk Power Corp., Buffalo, N. Y., will be the featured speaker at the Northeast Region banquet November 2. The banquet will be held in the main ballroom of Hotel Niagara, Niagara Falls, N. Y. beginning at 7:30 pm.

Mr. Macleod, a native of Massachusetts, lives at Grand Island, N. Y. and has his business offices in Buffalo. In Buffalo he is active in, or an officer of numerous commercial and civic organizations ranging from the Buffalo Municipal Research Bureau to the Council of Churches of Buffalo and Erie County. He is president of the Empire State Chamber of Commerce, Family Service Bureau of Buffalo and a past officer of such organizations as the Niagara Falls Community Chest, and U. S. Junior Chamber of Commerce.

He is author of a book "Cinderella Island," a history of Grand Island in the Niagara River and was awarded the Valley Forge Honor Medal of Freedom Foundation for his address at the annual meeting of the Chamber of Commerce of the United States at Washington, D. C., on May 3, 1950.

Membership and Chairman Certificates Are Available

Certificates of membership in the National Association of Corrosion Engineers and certificates for past chairmen of regions and sections are now available from Central Office, NACE. A. B. Campbell, executive secretary, said the certificates were authorized by the association's board of directors March 6.

Membership certificates, which measure 5½ by 8½ inches, are signed by the president and the executive secretary. They will be supplied on request at \$2 each, remittance in advance.

Certificates intended for presentation to regional and section chairmen are 9 by 12 inches, are made from an engraved plate and will be supplied on request from the region or section, the cost to be classed as a non-reimbursable expenditure. Certificates may be issued retroactively if desired. The cost of these certificates is \$7.50 each.

The Bibliographic Survey of Corrosion for the years 1950-51 includes 4454 abstracts of literature topically indexed and cross-indexed.

Nineteen Papers—

(Continued From Page 72)

periences of the Louisville, Ky., Joint Electrolysis Committee.

A program of activities has been arranged for ladies accompanying registrants for the meeting.

(A detailed program was published in August CORROSION beginning on Page 67.)

Northeast Region's—

(Continued From Page 73)

Drainage Current Distribution in Cathodic Protection by Marshall E. Parker, Corrosion Consultant, Houston. Mr. Parker, who has been engaged in corrosion work since 1945, has been a consultant since 1949. He has a BS from Sam Houston College and a BA from Rice Institute and is a registered Texas professional engineer. Author of numerous articles on corrosion control, he is active in several NACE technical committees and conducts a correspondence school in corrosion engineering.

Cathodic Protection of Lead Cables in an Urban Area by Lester M. Plym, Illinois Bell Telephone Co., Chicago. He has been interested in lead sheath cable corrosion in an advisory capacity for many years. He also has participated in the design of several cathodic protection systems. He holds bachelor and professional degrees in electrical engineering and is a member of NACE and the Western Society of Engineers. Presently he is Electrical Coordination Engineer for his company.

Committee Approach to Cooperation by Carl A. Erickson, Jr., Corrosion Engineer for The Peoples Natural Gas Co., Pittsburgh. Mr. Erickson, who holds an AB from Hobart College in 1947 and an MS, University of Chicago in 1943, has been corrosion engineer for his company since 1947. He presently is chairman of the Western Pennsylvania Corrosion Committee.

Organization and Experiences of the Louisville, Ky., Joint Electrolysis Committee, Underground Plant Protection of Paddy Run Power Station, Louisville, Ky.; Floodwall Protection of Canal Power Station, Louisville, Ky., by Lewis P. Aker and Stuart H. Gates and Care and Feeding of Half Cells by Lewis P. Aker, Lewis P. Aker, chemical engineer, Louisville Gas and Electric Co., has attended University of Missouri, University of Illinois and University of Louisville. He holds a BS in ChE 1926 and M ChE 1945. For 28 years he has been concerned with corrosion problems, principally allied to boilers and feedwater but has been involved in electrolytic corrosion problems for about six years. He is a member of ACS, National Association of Power Engineers and NACE.

Stuart H. Gates, Division Protection and Protection Engineer, Southern Bell Telephone and Telegraph Co., Louisville, has been chairman of the Louisville Joint Electrolysis Committee since 1938 and has supervised electrolysis mitigation work in Kentucky since that time. He has been interested in electrolysis since 1923. He attended University of Kentucky, Lexington.

South Central Region Technical Program Changes Are Listed

Several changes and additions have been made in the technical program for the 1955 South Central Region meeting to be held October 18-21 at the Shamrock-Hilton Hotel, Houston. The principal change is the dropping of the previously planned Roundtable discussions scheduled October 20 and 21 and substituting for them a series of pipeline group discussions. The tentative program published beginning on page 77 in the September issue of CORROSION is unchanged except as follows:

Recirculated Water Symposium—Thursday, October 20, beginning at 9 a.m. The following papers have been added:

Factors Other Than Mineral Content Which Determine the Corrosiveness of Cooling Water by E. H. Hurst, National Aluminate Corp., Chicago, Ill.
Experience with Silicate as a Corrosion Inhibitor in Cooling Water by John Woods and J. S. Beecher, E. F. Drew & Co., New York City.

Oil and Gas Production Symposium—Thursday, October 20, beginning at 2 p.m. The following title of a paper previously scheduled has been substituted:

Alcoplate—A New Material for the Corrosion Engineer by W. L. Clark, Alco Products, Inc., Dunkirk, N. Y.

Cathodic Protection Symposium—October 21, beginning at 2 p.m. The following papers have had a change in authorship:

Cathodic Protection Rectifiers: Some Factors to Be Considered in Specifications and Design by Ray M. Wainwright, University of Illinois, Urbana and Earl L. Newmeyer, Good-All Electric Mfg. Co., Ogallala, Neb.
Application of Cathodic Protection to Inside Tank Bottoms by J. H. Graves, Tidal Pipe Line Co., Joinerville, Texas.

Pipeline Corrosion Group Discussions will be held from 9 a.m. to noon October 21. There will be several groups of about 30 with two discussion leaders to each group.

Registration for Houston Meeting Opens Oct. 17

Registration for the October 18-21 meeting of South Central Region in Houston October 18-21 will open Monday evening. Registration fees of \$10 for men and \$6 for women will be accepted all day Tuesday, Wednesday and Thursday and Friday morning.

The registration desk will be in the corridor to the right of the lobby of the Shamrock-Hilton at the hotel's convention registration desk. The official program will be available there containing the detailed schedule of events and abstracts of technical papers.

The number of authors listed in the 1950-51 Bibliographic Survey of Corrosion published by the NACE is 4047.

Variety of Entertainment Scheduled for Meeting

Entertainment scheduled during the October 18-21 meeting of South Central Region at Houston is as follows:

Ladies—A hospitality room will be available all day Tuesday, Wednesday and Thursday. Entertainment planned includes a coffee, luncheon and style show.

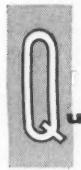
Pool Side Buffet—Includes entertainment by Roving Troubadors, a magician and Shamrock Corkettes.

Anniversary Party—A dance and midnight breakfast will be held in the Emerald Room of the Shamrock on Thursday, celebrating the Tenth anniversary of the incorporation of NACE.

Regional Past Chairmen Will Get Certificates

Certificates will be presented to eight past chairmen of South Central Region at a noon October 21 meeting during the region's 1955 session at the Shamrock-Hilton Hotel, Houston. This is one of the events at the luncheon which will have Frank L. Whitney, Jr., Monsanto Chemical Co., St. Louis, NACE president as principal speaker.

Scheduled to receive certificates are: A. N. Horne (1947); Donald Good (1948); Nathan Schofer (1949); T. R. Statham (1950); George Mills (1951); M. C. Fleming (1952); H. E. Waldrup (1953) and H. L. Bilhartz (1954). Wives will accept certificates for Messrs Good and Mills, both deceased.



What is the real worth of Cathodic Protection?

The real worth of cathodic protection depends primarily upon its effectiveness after it is installed. Inadequately designed or improperly installed systems will not do the job. Savings on your corrosion control costs can best be obtained with experienced E. R. P. corrosion engineers working with your staff.

Successful cathodic protection requires careful investigation and correct interpretation of all factors affecting the corrosion of any buried or submerged structure. When you use Electro Rust-Proofing cathodic protection services, you are assured of a successful installation, for E. R. P. brings to each job a background of 20 years experience in survey, design and installation of cathodic protection systems.

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Topics and Speakers Named for Berkeley Course



SIX PAST CHAIRMEN and the current chairman of North Texas Section received chairman certificates at a section meeting in Fort Worth September 12. They are (left to right) Tom R. Statham (1948-49); Guy C. Crawford (1950-51); H. L. Bilhartz (1951-52); J. C. Spalding, Jr. (1953); J. Gordon Meek (1954); Paul C. Fleming (1955). (K. D. Wahlquist (1949-50) was absent when this photograph was taken.)

Certificates Awarded at Fort Worth Ceremony

Approximately 30 members and guests attended the September 12 meeting of North Texas Section at Cattlemen's Restaurant, Fort Worth. A brief talk on the history of the section was given by Paul C. Fleming. Chairman and past chairmen certificates were presented to the following persons in appreciation of their work:

Tom R. Statham, Magnolia Pipe Line

Co., Dallas, Chairman 1948-49; K. D. Wahlquist, Southern Union Gas Co., Dallas, Chairman 1949-50; Guy C. Crawford, Service Engineers, Inc., Fort Worth, Chairman 1950-51; H. L. Bilhartz, Production Profits, Inc., Dallas, Chairman 1951-52; J. C. Spalding, Jr., Sun Oil Company, Dallas, Chairman 1953; J. Gordon Meek, Metal Goods Corp., Dallas, Chairman 1954.

Persons Responsible for Houston Meeting Named

Among the persons responsible for the 1955 South Central Region meeting at Houston are:

A. E. Richey, Cathodic Protection Service, Houston, general chairman.
J. A. Caldwell, Humble Oil & Ref. Co., Houston, assistant to the general chairman.

H. E. Morris, Monsanto Chemical Co., Texas City, technical program chairman.
O. W. Wade, Transcontinental Gas Pipe Line Co., Houston, arrangements.
C. A. Blanchard, Houston Natural Gas Co., finance.

A. L. Stegner, Tennessee Gas Transmission Co., Houston, entertainment.

Ira Mayhew, Houston, publicity.
J. J. Clemens, Dow Chemical Co., Houston, registration.

Mr. and Mrs. T. F. P. Kelly, Mavor-Kelly Co., Houston, ladies' program.
A. D. Simpson, Jr., United Gas Corp., Houston, printing.

M. A. Riordan, Rio Engineering Co., Houston, properties.

Detroit Section Meeting

The annual social meeting of the Detroit Section was held September 29 at the Walker Distillery in Walkerville, Ontario.

Approximately 50 members and their wives viewed a movie showing the process of producing whiskey and heard a brief discussion on corrosion problems in a distillery. This was followed by a tour of the distillery and climaxed with a smorgasbord.

Petroleum, Chemical Industry Problems to Be Session's Topics

A tentative outline of the 3-day Short Course on Corrosion Problems in the Process Industries to be held at Berkeley, Cal. has been prepared. The short course is being given November 14-16 by the University of Southern California at Berkeley in cooperation with the Western Region, National Association of Corrosion Engineers. It immediately precedes the region's fall meeting in San Francisco on November 17-18.

The subject matter of the course is related to the petroleum and chemical industries.

The tentative program released for publication by Prof. I. Cornet, Associate Professor of Process Engineering, University of California, Berkeley, is as follows:

Monday, November 14

8-8:45 am—Registration.
8:45-9 am—Welcome.
9:10-20 am—Equipment Inspection in Process Plants, Edward H. Tandy, Standard Oil Company of California, El Segundo.
10:30-12 noon—Corrosion Testing in Process Plants, F. L. Whitney, Jr., Monsanto Chemical Co., St. Louis.
1:30-3:20 pm—Handling Sulfuric Acid, R. J. Hafsten, Standard Oil Company (Indiana), Whiting.
3:30-5 pm—Handling Caustic, G. J. Puckett, The Dow Chemical Co., Pittsburgh, Cal.

Tuesday, November 15

9:10:20 am—Furnace Stack Corrosion, Dean Burgan, Electric Steel Foundry Co., Portland, Ore.
10:30-12 noon—High Temperature Problems in Process Plants, John J. B. Rutherford, The Babcock and Wilcox Co., Beaver Falls, Pa.
1:30-5 pm—Special Metallurgical Problems, G. A. Nelson, Shell Development Co., Emeryville, Cal.; W. B. DeLong, E. I. duPont de Nemours & Co., Wilmington, Del.

Wednesday, November 16

9:10:20 am—Metallic Linings for Corrosion Protection, S. J. Artese, Shell Oil Company, New York.
10:30 am-12 noon—Non-Metallic Linings for Corrosion Protection, Raymond B. Seymour, Loven Chemical Co., Newhall, Cal.
1:30-3:20 pm—Cooling Water Problems, Charles P. Dillon, Carbide and Carbon Chemicals Co., Texas City, Texas.
3:30-5 pm—Cathodic Protection in the Process Industries, George A. Works, Union Oil Co. of Cal., Rodeo.

Registrations will be accepted in advance or will be taken at the first meeting November 14. The fee is \$30. Further information may be had from Department of Conferences and Special Activities, University of California Extension, Berkeley 4, Cal.

Marine Corrosion Course

A 1956 Conference on Marine Corrosion and Fouling Problems is contemplated by the University of California at its La Jolla campus.

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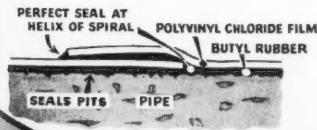
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1. **HIGHEST SHOCK-IMPACT RESISTANCE**... Made of tough polyvinyl chloride film laminated to butyl rubber, Plicoflex Tapes offer the extra protection of more-than-double thickness together with resiliency which prevents damage during backfilling operations.

2. **INCREASED SOIL STRESS RESISTANCE**... Here's an added bonus created by the unique Plicoflex *laminated* construction...available only in Plicoflex!

3. **NO MOISTURE MIGRATION**... The sketch below shows how the outstanding cold-flow properties of the butyl rubber provide a perfect seal at the helix of the spiral overlap. Air and moisture are literally squeezed out... can't get in again...can't migrate under the protective coating.



4. **STRONGER PERMANENT BOND**... Plicoflex sets up quickly. Exhaustive tests show that within two weeks after application, Plicoflex "cures" to form an *inseparable* bond to the pipe, even on irregular surfaces. Moreover, the tape itself will not delaminate in use.

5. **UNIFORM THICKNESS**... Rigid factory inspection assures the user that the Plicoflex system of coatings will be of uniform quality and uniform thickness. Thus the user knows he can depend on Plicoflex to give equal all-over protection.

6. **SELF-HEALING PROPERTIES**... The cold-flow characteristics of butyl rubber provide another bonus, flowing into and sealing holidays that may occur in the tape film due to mechanical damage.

7. **BUILT-IN COLOR-CODING**... Available in black, white, and 6 brilliant colors, Plicoflex Systems provide virtually maintenance-free method of color coding for above-ground plant installations. No painting required — the color is in the tape!

8. **LOW COST**... Unique Plicoflex application systems cut coating manpower requirements to a minimum. You benefit from lower first cost as well as lower maintenance costs.

9. **ADHESIVE PRIMERS**... Factory-produced to thoroughly tested formulae and rigidly inspected for quality and uniformity, Plicoflex adhesive primers are available to suit practically every normal requirement.

10. **EXPERIENCE**... Plicoflex systems have been engineered and produced by men long experienced in corrosion protection of pipelines. This is our primary interest — not a by-product of other interests.

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Programs Announced for Seven Dinner Meetings of Southwestern Ohio Section

Programs have been arranged for seven meetings of Southwestern Ohio Section at Shuller's Restaurant, Reading, Ohio. All meetings start at 6:30 pm with cocktails. The December 6 inspection trip will be an exception. It starts at 2:30 pm at Cincinnati Milling Machine Company auditorium. After the trip the dinner meeting will be held at Shullers.

The schedule is as follows:

Oct. 25—Scope of Corrosion Engineering, T. J. Maitland, American Telegraph and Telephone Co., New York, N.Y.

Nov. 29—Illustrations of Corrosion, M. G. Fontana, Ohio State University, Columbus.

Dec. 6—Inspection trip and corrosion film, Cincinnati Milling Machine Co. Dinner and meeting follow at Shuller's Restaurant, Reading.

Jan. 31—Causes of Corrosion—Part 1, Sol M. Gleser, A. M. Kinney Co., Cincinnati.

Feb. 28—Causes of Corrosion—Part 2, Wm. Spurgeon, General Electric Co.

Mar. 27—Methods of Corrosion Control, Frederick Fink, Battelle Memorial Institute, Columbus.

April 24—Panel Discussion: Protective Coatings, Atmospheric Coatings, Cliff Weymiller, Procter & Gamble Co.; Underground Coatings, George Pemberton, Cincinnati Gas and Electric Co.; Ceramic Coatings, William Barrows, Barrows Porcelain Enamel Co.

CERTIFICATES of MEMBERSHIP in NACE

Certificates of membership in the National Association of Corrosion Engineers will be issued on request at \$2 each, remittance in advance. The certificates, which measure 5½ x 8½ inches, are signed by the president and executive secretary of the association.

CERTIFICATES for PAST CHAIRMEN of REGIONS and SECTIONS

Certificates measuring 9 x 12 inches in size, prepared from an engraved plate, are available for issuance to regional and sectional chairmen. They will be supplied on request of the region or section at \$7.50 each to be paid by the region or section, the cost to be classified as a non-reimbursable expenditure.

Address Orders to

A. B. Campbell, Executive Secretary

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

1061 M & M Bldg., Houston 2, Texas

Six Meetings Planned By Cleveland Section

Cleveland Section has scheduled programs for six meetings during the remainder of this year and through May of 1956. New officers effective with May 1955 are as follows: R. C. Weast, Case Institute of Technology, chairman; L. H. Schwalm, Ohio Bell Telephone Co., vice-chairman; A. G. Hose, Lindsay Wire Weaving Co., secretary-treasurer, all of Cleveland.

The program is as follows:

October 11—Corrosion of Internal Combustion Engines by Dr. Aseff.

November 8—Case History of Cathodic Protection Installation by Bernard Husock, Harco Corp.

January 10—Joint meeting with The Electrochemical Society.

February 14—Corrosion in Military Installations by Col. Lindsay M. Applegate, U. S. Army Corps of Engineers, Omaha.

April 10—Corrosion in the Petroleum Industry by L. Mills.

May 15—Stress Corrosion by Julius J. Harwood, Office of Naval Research, Washington, D.C.

All meetings except the April meeting will be held in Hotel Manger.

Chicago Section Schedules Programs for 7 Meetings

Seven meetings have been scheduled by Chicago Section beginning with an October 18 session. All meetings are at Chicago Engineers' Club, 315 South Federal St., Chicago. The schedule is as follows:

October 18—Burke Douglas, Dow Chemical Co. will speak on Development of Galvomag Anodes and Their Uses.

November 15—C. G. Munger, Amercoat Corp. will discuss Corrosion and Design.

January 17—C. H. Samans, Standard Oil Research Laboratories will discuss Corrosion Measurements.

February 21—M. G. Fontana, Ohio State University will discuss Various Approaches to Corrosion Problems.

March 20—D. C. Glass, Pure Oil Company will discuss Survey of Pipeline Coating Practices and Protection Costs.

April 17—E. F. Moorman, International Harvester Co. will discuss Economic Control of Corrosion Under Mildly Corrosive Conditions.

May 15—F. L. Whitney, Jr., Monsanto Chemical Company will speak on Use of Plastics to Solve Corrosion Problems in Industry.

Seymour Paper Data by Atlas Mineral Products Co.

Data, charts and photographs included in the article "Plastic Pipe for Underground Structures," by R. B. Seymour, published in CORROSION's July issue, were made available by the Atlas Mineral Products Company, Mertztown, Pa.

Corrosion is available on a subscription basis to non-members of NACE.

More than 1400 copies of Corrosion are mailed monthly to addresses outside the United States.

Greater Boston Section Will Meet at Brookline

Meetings of Greater Boston Section are planned to be held at Hotel Beaconsfield, Brookline, Mass. as follows:

December 7—Ceramic Coatings by M. Cannistraro, The Bettinger Corp.

February 8—Corrosion of Light Metals, E. D. Verink, Jr., Aluminum Company of America.

May 2—Organic Coatings, Kenneth Tator, Kenneth Tator Associates.

Officers of the section effective July 1 are Murray M. Jacobson, Watertown Arsenal Laboratories, Watertown, Mass., chairman; Edward C. Rue, Boston Edison Co., vice-chairman; Wayne H. Keller, National Research Corp., Cambridge, Mass., secretary-treasurer.

Genesee Valley Section Sessions Start October 18

Six meetings have been planned by Genesee Valley Section beginning with October 18. Information available on these meetings has been released as follows by D. K. Priest, The Pfaudler Co., Rochester, secretary-treasurer of the section:

October 18—German Club, Round table discussion about aluminum in architectural uses.

November 14—Joint meeting with American Society for Metals. Subject not decided.

January 17—German Club. Tentative: Electroless plating.

February 15—Joint meeting with American Institute of Chemical Engineers. Subject: Kel-F coatings.

March 20—German Club. Subject not decided.

April 17—German Club, Annual business meeting. Motion picture.

Assuming office July 1 in addition to Mr. Priest were: N. B. Carter, Eastman Kodak Co., Rochester, chairman; J. V. Atkin, Rochester Gas & Electric Corp., Rochester, vice-chairman.

New Officers to Take Over At Pittsburgh October 6

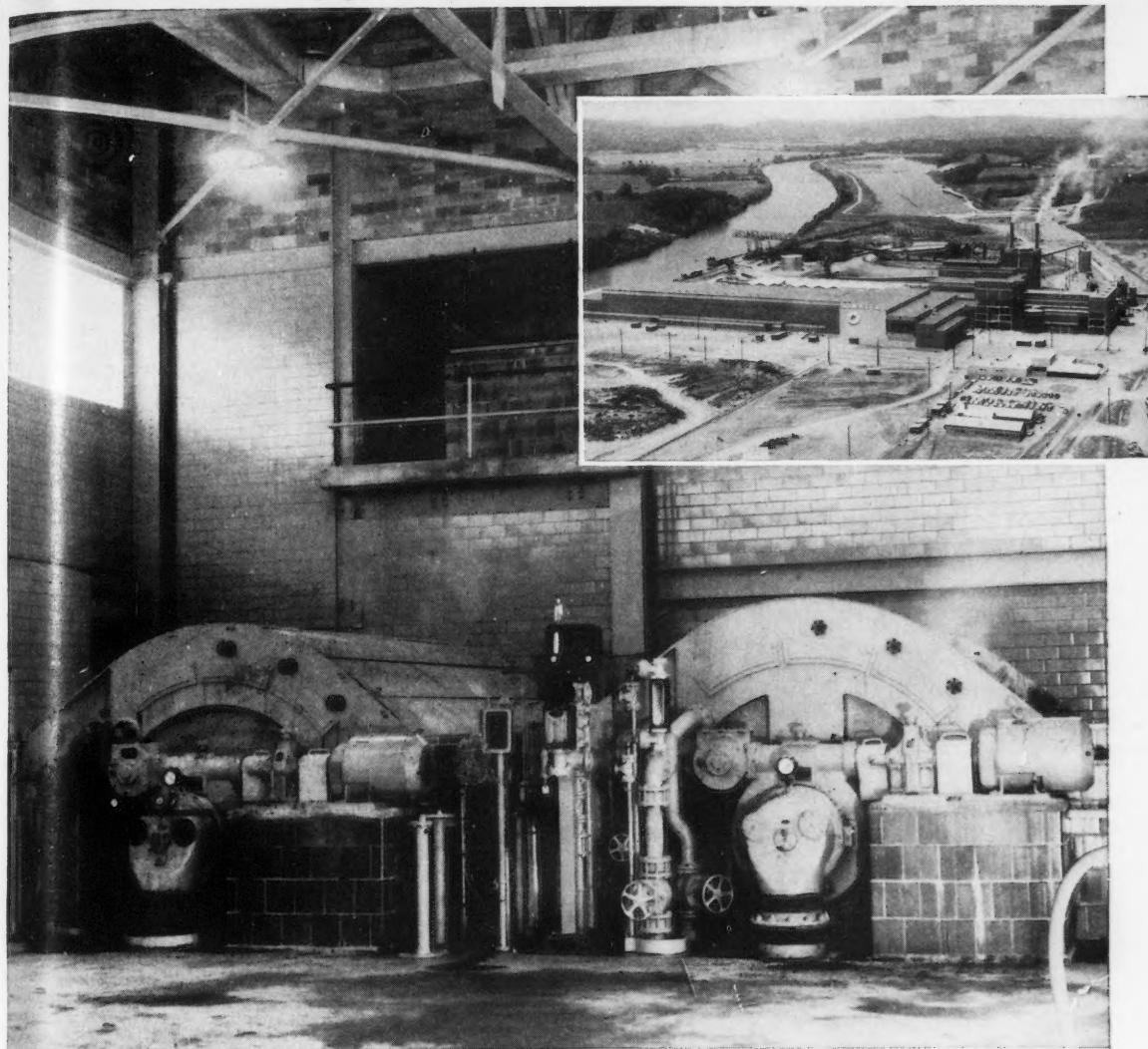
William G. Renshaw, Allegheny Ludlum Steel Corp., Brackenridge, Pa. takes over the chairmanship of Pittsburgh Section October 6. At the same time the other offices of the section will be assumed as follows: L. G. Royston, Royston Laboratories, Inc., Blawnox, Pa. becomes vice-chairman; Arvil B. McKee, Aluminum Co. of America, New Kensington, Pa. becomes secretary and Wallace P. Cathcart, Tank Linings Corp., Pittsburgh, starts another term as treasurer.

Meetings have been scheduled as follows at Mellon Institute, Oakland, Pa.: October 6, November 3, December 1, January 5, February 2, March 1, April 5, May 3.

Board Meeting Scheduled

Business of South Central Region will be conducted at a luncheon meeting of the region's board of trustees Wednesday, October 19. The luncheon will be held at the Shamrock-Hilton Hotel during the region's 1955 annual meeting.

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North Texas Section Plans Variety of Subjects

A wide variety of subject matter is scheduled to be covered in eight meetings planned by North Texas Section beginning with an October 3 session which will be addressed by Malcolm Mitchell, Director of Research, Reilly Tar and Chemical Co., on the subject "Pipeline Coatings." The meeting will be held in Dallas.

Other meetings scheduled are, some with unconfirmed programs subject to change:

- November 7—Dallas. Wrought Iron Corrosion.
- December 5—Fort Worth, Instrumentation for Corrosion Measurements by Bethel Bond, Cathodic Protection Service.
- January 9—Dallas. What's What in Plastics by W. M. Thornton, Atlantic Refining Co.
- February 6—Dallas. Cathodic Protection Ground Beds by J. L. Pool, Magnolia Pipe Line Co.
- March 5—Fort Worth. Submerged Combustion by Walter Hart, Gulf Oil Corp.
- April 2—Dallas.
- May—Dallas. Annual picnic.

Sabine-Neches Programs Center on Petroleum

Programs scheduled by Sabine-Neches Section during the next seven months are concerned principally with corrosion problems in the petroleum industry. All meetings are scheduled tentatively to be held in Orange.

The schedule follows:

- October 27—External and Internal Coatings of Storage Tanks by Crawford Chaisson, Cities Service Corp., Lake Charles, La.
- December 8—Panel Discussion on Refinery Corrosion Problems. Chris Murray, Pure Oil Company, Port Neches, Texas, moderator.
- January 19—Copper Base Alloys. Al Wafer, Ohmstede Machine Works, Beaumont.
- February 23—Corrosion Problems in High Speed Rotary Compressors by A. D. Hardgroder, Mathieson Chemical Corp., Lake Charles, La.
- March 29—Panel Discussion on Plant Painting Problems. Vernon Brown, Columbia-Southern Chemical Corp., Lake Charles, La., moderator.
- April 26—Corrosion Problems in the Gas Industry, Joe Waterfield, United Gas Corp.
- May 24—Social program.

Philadelphia Section to Have Panel October 14

Philadelphia Section will meet Friday, October 14 at the Poor Richard Club in Philadelphia.

A round table discussion is planned, with the panel to consist of H. H. Bennett, Socony Mobil Oil Company; Robert Pope of Bell Telephone Company; Michael Monnack, E. I. du Pont de Nemours; Charles P. Dillon, Carbide and Carbon Chemical Company; C. R. Payne, Electro Chemical Engineering & Supply Company.

Looking Forward to NOVEMBER ISSUE

Articles scheduled for publication in the November Technical Section of Corrosion are:

The Corrosion Behavior of Aluminum by Hugh P. Godard, Aluminum Laboratories, Ltd., Kingston, Ont.

Control of Couples Developed in Water Systems by G. B. Hatch, Calgon Inc., Pittsburgh.

Corrosion of Lead-Lined Sulfuric Acid Evaporators by W. J. Cotton, W. J. Cotton Laboratories, Milwaukee.

Electrochemical Studies of the Hydrogen Sulfide Corrosion Mechanism by Scott P. Ewing, Carter Oil Company, Tulsa.

A Note on the Value of Ammonia Treatment for Tank and Casing Annulus Corrosion by Hydrogen Sulfide by W. F. Rogers, Gulf Oil Corp., Houston.

Use of Ammonia to Prevent Casing Corrosion by H. E. Greenwell and Radio Loncaric, Atlantic Refining Co., Dallas and Harry G. Byars, Fort Worth.

Technical Committee 1J Report. Part 1—Long Term Strengths of Reinforced Plastics Determined by Creep Strengths. Part 2—Microscopic Examination as a Test Method for Reinforced Plastic Pipe by H. D. Boggs, Fibercast Corp., Sand Springs, Okla.; Carl de Ganahl, Spiral-Glass Pipe Co., New Brunswick, N. J., and B. W. Bradley, Shell Oil Co., New York.

A Memo on Protecting Pipe Type Cables by F. E. Kulman, Consolidated Edison Co. of New York, N. Y.

Carolinias Section Meeting Due Late in November

A meeting has been scheduled for late November by Carolinas Section. The exact date and program have not been determined.

The following have been elected permanent officers: Robert D. Williams, Celanese Corp., Charlotte, N. C., chairman; Rodney B. Teel, The International Nickel Co., Inc., Harbor Island, N. C., vice-chairman and William C. Burnett, Southern Bell Telephone and Telegraph Co., Charlotte, N. C., secretary-treasurer.

The section was organized earlier in the year and approved as of April 1 by the Southeast Region board of governors.

Surface Potentials Topic At First Tulsa Session

Tulsa Section plans four meetings, all at the Mayo Hotel, Tulsa beginning with an October 24 session on surface potentials. Other meetings scheduled are:

November 28—Corrosion clinic to cover: Coatings, rectifiers, inhibitors, galvanic anodes.

December 26—Christmas party.

January 23—Protective coatings.

Cement Lined Pipe Topic At Permian Basin Meeting

At the July 11 meeting of Permian Basin Section held at the Lincoln Hotel in Odessa, approximately 14 members and 19 guests heard E. O. Kemper of Permian Enterprises, Inc., speak on "Cement Lined Pipe, Its History, Application and Construction."

Following Mr. Kemper's talk, a meeting of the chairmen of the various committees directing the Sixth Biannual Corrosion Tour was held.

Montreal Elects New Officers for Section

The following have been elected officers of Montreal Section for the 1955-56 season: W. V. Papineau, Dearborn Chemical Company, chairman; W. E. Dempster, Aluminum Company of Canada Limited, vice-chairman; M. D. Phillips, McCall-Frontenac Oil Company Limited, secretary-treasurer. All are of Montreal.

Vancouver Section Meeting

Plastics for Corrosion Resistant Applications will be discussed by Dr. Raymond B. Seymour, Loven Chemical Co., Newhall, Cal. at the October 31 meeting of Vancouver Section.

Larrabee, Seagren Named Delegates to ISCC

C. P. Larrabee, chairman of the Technical Practices Committee and G. W. Seagren, Mellon Institute of Industrial Research have been appointed NACE delegate members on the Inter Society Corrosion Committee for the year 1955-1956.

Some Lecturers Listed For Illinois U. Course

Some of the lecturers who will participate in the University of Illinois short course on corrosion December 5-9 have been named. The course, to be held at the university in Urbana, will be limited to consideration of cathodic protection and associated subjects. Only 50 registrants will be accepted.

Those named as lecturers are Norman Hackerman, University of Texas; Marshall Parker, Houston; H. H. Uhlig, Massachusetts Institute of Technology Corrosion Laboratory.

R. M. Wainwright and H. S. Hayward, professors at University of Illinois also are acting on the short course staff.

Corrosion Show Contracts

The 1956 NACE Corrosion Show to be held at the Hotel Statler in New York, March 12-16, will occupy the main ballroom, the East Room, West Room, Rotunda, Georgian Room and Georgian Room Foyer. There will be 123 exhibit booths available.

Contracts and floor plans of the exhibit area may be obtained by writing A. B. Campbell, Executive Secretary, 1061 M & M Building, Houston 2, Texas.

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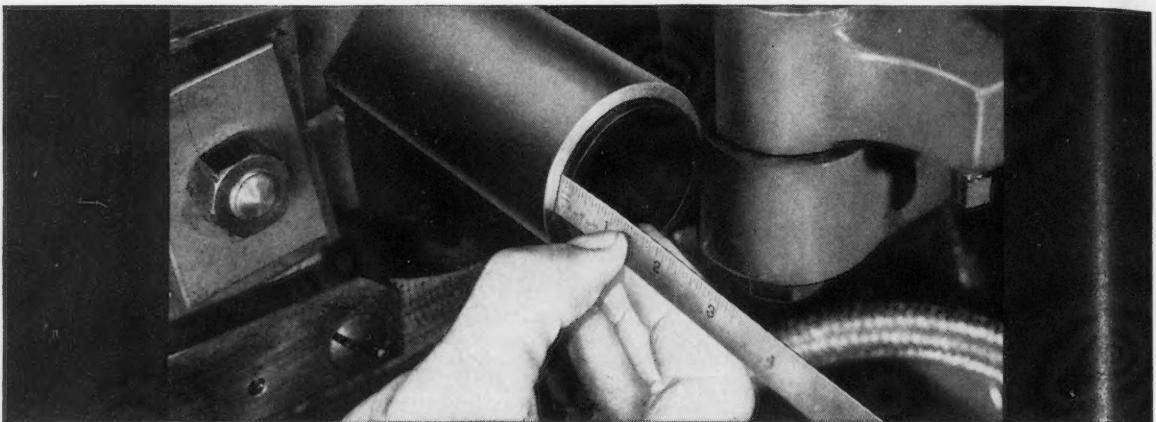
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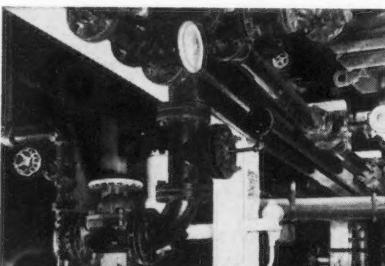
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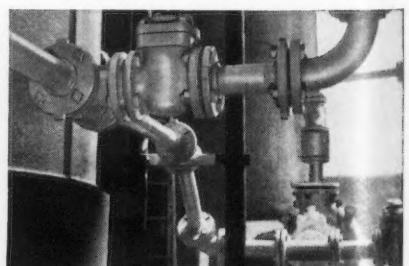
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General News

Australian Corrosion Symposium Papers Listed

Corrosion Papers Among 60 Scheduled by AWS

Numerous applications and advances in welding will be considered during the October 17-21 National Fall Meeting of the American Welding Society in Philadelphia. More than 60 papers covering carbon dioxide-shielded metal arc welding; advances in welding titanium and molybdenum and application of welding to shipbuilding, piping, pressure vessels, machinery and other structures will be given.

Among the papers are:

Effect of Preheating on Stress-Corrosion Cracking of Steel Weldments by E. Paul DeGarmo and I. Cornet, University of California.

Backing Ring Elimination Permits Ultrasonic Testing and Avoids Cracking of Piping Welds by Wilfred A. Pollock, Wisconsin Electric Power Co.

Permeability and Crack Sensitivity of Stainless Steel Welds by John L. Lang and Charles Wright, Jr., Lukens Steel Company.

Welding of Titanium, by E. F. Gorman, Linde Air Products Co.

Resistance Welding Ductile Joints in Commercially Pure Titanium by Robert Wickham, Marquardt Aircraft Co.

The Practical Approach to the Welding of Stainless Steel Pressure Vessels by Frederick H. Clash, Jr., Link Belt Company.

Many Items of Corrosion Interest on FPVPC Agenda

Among the papers to be presented during the October 3-5 33rd Annual Meeting of the Federation of Paint and Varnish Production Clubs are the following:

Effect of Modifiers on the Chemical Resistance of Vinyl Films by Northwestern PVPC.

Some Aspects of Polyvinyl Paint Formulations by CDIC Paint and Varnish Production Club.

Result of Researches of the Belgian Corrosion (Protective) Committee by Dr. M. Daniel Bermame, Head, Corrosion Study Commission, Brussels, Belgium.

A meeting of the PVPC corrosion committee will be held at 12:30 pm October 4; a round table discussion on corrosion will be held at 11 am October 5 and a report of the Federation Corrosion Committee will be given by Dr. Joseph W. Tomecko, chairman at 10:30 am October 5.

Four Bibliographic Surveys of Corrosion have been published by NACE covering literature published in the years 1945-51 inclusive.

Australian Inter Society Liaison Committee Formed

An Inter Society Liaison Committee has been named by the Australian Association for Corrosion Prevention with C. W. Brewer, Metallurgy Dept., Swinburne Technical College, Melbourne, as chairman.

The corrosion prevention association was organized recently to promote cooperation of governmental and industrial organizations in relation to corrosion and its mitigation and to promote interest in corrosion control by promoting lectures, symposia and publications relating to corrosion control.

Case Institute Offers Corrosion Related Theses

Among the abstracts of theses submitted during the 1954-55 year in partial fulfillment of the degree of doctor of philosophy and master of science at Case Institute of Technology are some related to corrosion phenomena. Copies of complete theses may be obtained in microfilm form at \$1.50 per thesis from Supervising Librarian, Case Institute of Technology, Cleveland, Ohio.

Titles and authors of theses of corrosion importance are:

Scaling of Zirconium at Elevated Temperatures by Domenick J. Garibotti.

Ductility of Steels with Different Amounts of Hydrogen by T. Toh.

Hopkinson Is Elected By Lubrication Engineers

J. W. Hopkinson, president of Penn-Petroleum Corp., Detroit, has been elected president of the American Society of Lubrication Engineers. W. Deutsch, Trabon Corp., Cleveland, was elected vice-president at large; E. R. Booser, General Electric Co., West Lynn, Mass., is new secretary and W. H. Fowler, Jr., Pure Oil Co., Chicago, is treasurer.

Raborn Will Lecture

Robert H. Aborn, Director of Research Laboratories, United States Steel, Kearney, N. J., has been selected to deliver the Edward DeMille Campbell Memorial Lecture on October 19 immediately following the annual meeting of the American Society for Metals.

Empire Council in Canada

The 1957 Empire Council of Mining and Metallurgical Institutions Congress will be held in Canada by invitation of the Canadian Institute of Mining and Metallurgy.

Eight Organizations Join in Melbourne University Program

Eight commercial and government organizations are cooperating in the 1955 Symposium on Corrosion to be held November 28-December 2 at University of Melbourne, Australia. The organizers are, besides the university, The Institution of Engineers (Melbourne Div.), Royal Melbourne Technical College, Royal Australian Chemical Institute (Victorian Branch), Australian Institute of Metals (Melbourne Branch), Society of Chemical Industry (Victoria), Australian Institute of Mining and Metallurgy (Victorian Branch) and Australian Association for Corrosion Prevention.

Copies of a proceedings are expected to be available from Hon. Secretary, Symposium on Corrosion, Metallurgy Dept., University of Melbourne, at one pound, 10 shillings per copy.

The tentative program is as follows: Introductory Paper—Cost of Corrosion by H. K. Worner, Melbourne University.

Fundamentals

Mechanism of Corrosion by A. F. Dunbar, Royal Melbourne Technical College and H. A. Stephens, C.S.I.R.O. Anodic Inhibitors by T. P. Hoar, Cambridge University.

Contribution of Thermodynamics to Corrosion Theory by M. Pourbaix, Belgian Centre of Study on Corrosion. Corrosion Reaction Rates by G. M. Willis, Melbourne University. Corrosion and Stress by U. R. Evans, late of Cambridge University.

High Temperature Oxidation by J. Mills, Aeronautical Research Laboratories.

Anodic Passivation of Iron by W. T. Denholm, South Australian School of Mines.

Design and Interpretation of Corrosion Tests by F. L. LaQue, International Nickel Co., U.S.A.

Prevention

Paint Formulation and Selection for Atmospheric Exposure by J. Rischbieth, Defence Standards Laboratories.

Cathodic Protection by W. G. Waite, F. A. Hughes and Co., England.

Inhibitors with Special Reference to Recirculating Cooling Waters by R. N. Ride, Defence Standards Lab.

Temporary Corrosion Preventives by E. Kuster, Defence Standards Lab.

Vapour Phase Inhibitors by A. B. Cox and E. Kuster, Defence Standards Laboratories.

Buried and Immersed Corrosion

Theoretical Aspects of Soil Corrosion by K. Lorking, Aeronautical Research Laboratories.

(Continued on Page 84)

Australian Corrosion—

(Continued From Page 83)

Stray Current Electrolysis in Victoria by J. T. Dunn, Electrolysis Committee.

Corrosion Problems in the Marine Field by J. F. Bell, M. J. McLachlan and H. Laurie, Dept. of the Navy.

Biological Organisms and Corrosion Processes by C. D. Parker, M. and M. Board of Works.

Corrosion in Industry

Protection of Aircraft Structures by H. Arblaster and P. Thompson, Comm. Aircraft Corp.

Corrosion in Refinery Practice by R. W. Weiss and A. O. Wells, Standard Vacuum Refining Co.

Corrosion in Distribution Plant by N. S. Boas, Commonwealth Oil Refineries.

Chemical Aspects of Corrosion Prevention in the Power Station Water-Steam Cycle by W. Johnson, State Electricity Commission.

Special Problems in Design and Maintenance of Plant by J. McMahon, State Electricity Commission.

Corrosion of Boilers Cooling Zinc Concentrate Roaster Gases by J. Forster and A. Gordon, Electrolytic Zinc Co.

Problems in the Production of Nuclear Energy by K. F. Alder, A.E.R.E., Harwell.

Corrosion in the Chemical Industry—the Role of Microstructure of Alloys by R. J. Caney and B. Henshall, Imperial Chemical Industries Ltd.

Special Problems in the Paper Industry by W. White, Australian Paper Manufacturers Ltd.

Special Problems in the Gas Industry by R. J. Bennie and G. Lewis, Gas and Fuel Corporation.

Future Trends in Corrosion Prevention by A. G. Sussex, Defence Standards Laboratories.

BOOK REVIEWS

Industrial Maintenance Painting

By Paul E. Weaver. 82 pages, $5\frac{1}{2}$ x 8, cloth or paper. 1955. Published by Paul E. Weaver, 4025 Brady St., Baton Rouge 5, La. Per copy, cloth \$3.50; paper, \$2.50.

Based in part on his personal experience and prepared in anticipation of its use in part as a thesis toward a master's degree in mechanical engineering, the book crams a wide variety of information into small compass. Of especial interest are the tables which give unusually concise data on various aspects of industrial painting. Such subjects as Paint mils film thickness per 100 sq. ft. per gallon for different solids contents; data on sandblasting equipment, such as cost of leaks due to waste of air and others are included.

The author recommends the best surface preparation, sandblasting if possible and selection of paints on the basis of a rating system which includes type of exposure. Clear illustrations of spray painting technique are included. The data on surface preparation are more extensive than on other aspects of the painting problem.

Considerable information on the economics of painting is included. The author contends, for example, that performance data on sandblasting are not always accurate because there usually is inadequate information on the efficiency of the operations. The significance of relatively minor points, frequently ignored, is emphasized.

Aluminum Taschenbuch. Edited by Johannes Reiprich and Wilhelm v. Zweth. 11th Edition. (In German.) 965 pages, 5 by 7 inches, cloth. 1955. Aluminum-Verlag GMBH, 26/29 Jagerhofstrasse, Dusseldorf 22a, Germany. Price not indicated.

A thorough exposition of aluminum from the technical and industrial point of view. The 400 references and 170 tables cover the data on aluminum, with information taken from sources all over the world. The editors have canvassed 20 periodicals for additional data.

For the worker in aluminum proficient in German or who has translating services at his command this should be a useful and often referred to book.

Spot Tests. Volume 1—Inorganic applications. Fourth Edition, 518 pages, 6 by 9 inches, flexible cloth. 1954. Per copy \$6.50. Vol. 2—Organic Applications. Fourth Edition, 436 pages, 6 by 9 inches, flexible cloth. 1954. Per copy \$6.25. By Fritz Feigl. Translated by Ralph E. Oesper. Published by Elsevier Press, Inc., 2330 Holcombe Blvd., Houston, Texas.

Vol. 1: The fourth edition of this work published since 1931 is completely revised. Following a brief history of spot testing is a chapter on techniques by Ph. W. West. In Chapter 3, data are given on metals in the hydrogen sulfide

(Continued on Page 85)

"You're Right, there's a whale of a difference between coal tar and asphalt for pipe!"

"Last time we talked, old timer, you told me pipe coatings manufactured from coal tar pitch were better than asphalt. A few days ago I had the chance to see the big difference with my own eyes. We had to patch a line that was coated with asphalt and glass fiber. Water had gotten in through the wrapping and permeated the coating. The asphalt had lost its bond with the pipe—which I learn is one of the weak points of using asphalt for a coating. It just won't stick to the pipe like coal tar pitch does. Water will get through asphalt where it won't with coal tar pitch.

"Another thing I found out that whenever asphalt comes in contact with petroleum products it dissolves which diminishes its protective value as a coating.

"We called in the S. D. Day man and he suggested for a permanent, trouble-free coating and wrapping that we use Pitt-Chem Coal Tar Enamels and Ruberoid Asbestos Pipe Line Felt because the coal tar pitch used in these products have proven themselves well.

"We took his advice and he followed through on the job like he was on our payroll. I noticed too, that S. D. Day had all kinds of modern equipment for expediting materials and the aggressiveness to see that they get to the job in the field when needed. From my experience I know I can't go wrong by staying with S. D. Day and their coal tar pitch coating and asbestos wrapping."

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HOUSTON, TEXAS

Distributor:

PITT-CHEM Coal Tar Enamels
RUBEROID Asbestos Felts
FIELDJOINTERS
FORMULA 291—Skinsaver

BOOK REVIEWS

(Continued From Page 84)

group, ammonium sulfide group, ammonium carbonate group, alkali metals, ammonia and derivatives of ammonia. In Chapter 4 there are 30 items under the heading "Tests for Acid Radicals, Anions." Other chapters are: Tests for free anions, systematic analysis of mixtures by spot reactions, application of spot reactions in tests of purity, examination of test materials, studies of minerals; the last chapter includes 70 items. There is an alphabetical subject and an author index to extensive references.

Vol. 2: Spot test techniques are explained by Ph. H. West, after which the chapter headings include: Preliminary (Exploratory) Tests, Detection of Characteristic (Functional) Groups in Organic Compounds, (29 items), Identification of Individual Organic Compounds (51 items), Application of Spot Reactions for Special Technical and Scientific Purposes (36 items). This volume includes (as does Vol. 1) a chapter on limits of identification attained by spot tests. There is an author and a subject index.

Plastics for Corrosion-Resistant Applications. By Raymond B. Seymour and Robert H. Steiner. Aug. 23, 1955. 423 pages 5 $\frac{1}{4}$ by 8 $\frac{1}{2}$, cloth, Reinhold Publishing Corp., New York. Per copy \$7.50.

A thorough discussion of the modern use of plastics for industrial purposes. Much of the data are presented in tabular form and each of the sections is adequately referenced. A survey of some of the subject headings indicates the thoroughness of the work. For example, Section 3—Plastic Materials of Construction, contains the following subheadings: Protective coatings, organic linings, chemical resistant mortar cements, casting resins, cellular plastics, plastic impregnants, industrial adhesives and reinforced plastics.

Other sections are: General, thermoplastic applications, applications of plastics in masonry construction, plastics selection guide. The last section makes recommendations on the selection of specific materials to meet specific corrosion problems. Data are included on floorings, tank cars and trucks, exhaust and piping systems, paper mill applications, steel pickling, textile industry, food industry and others. Numerous tables of data are given. There is an author and an alphabetical subject index.

The number of authors listed in the 1950-51 Bibliographic Survey of Corrosion published by the NACE is 4047.

Abstracts published in the NACE Bibliographic Surveys of Corrosion are obtained from more than 28 abstracting agencies.

Abstracting services provided by NACE include: the Corrosion Abstracts Section of Corrosion magazine; the Bibliographic Surveys of Corrosion and the NACE Abstract Punch Card Service. Details about any of these can be obtained by writing NACE Central office, 1061 M & M Bldg., Houston 2, Texas.

PAINTING ANALYSIS

Learn how new Glidden painting service can help you cut corrosion costs!

Now Glidden offers a no-cost, no-obligation analysis of *any painting problem*. This new service can be as comprehensive as you wish—anything from stain for a paneled office to special paint formulations to end corrosion on a water tower.



New Formula NEV-A-RUST dries to a sparkling, high gloss; has greater resistance to rust, acid, gases, fumes. Ideal for structural steel, iron fences, grillwork, smokestacks, metal roofs and all metal surfaces.

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NEW PRODUCTS —Materials—Service—Literature

Porous Teflon and Kel-F filters are made by Porous Plastic Filter Co., Glen Cove, N. Y.

Stainless steel, welded diaphragm-type packless expansion joints which help solve vibration and expansion control problems are available from T. R. Finn & Co., Inc., Industrial Division, Hawthorne, N. J.

Modern Filtration is the title of a cata-

log available from Permanent Filter Corp., 1800 West Washington Blvd., Los Angeles, Cal. Sintered bronze filters made by fusing balls into a porous element are described.

Magnesium and zinc anodes' output in salt water may be tested by the 0-5 ampere meter designed by Agra Instrument Co., 6517 East 6th St., Tulsa, Okla. The meter is used with inexpensive external shunts finished with a

short length of resistance wire for adjusting anode output.

Architectural application of aluminum is explained in two booklets, Alcoa Architectural Aluminum: Care During Construction and Alcoa Architectural Aluminum: Cleaning and Maintenance, available from 768 Alcoa Bldg., Pittsburgh 19, Pa.

Aluminum building wire in sizes from single strand to 61-strand is made in the Newark, Ohio, plant of Kaiser Aluminum & Chemical Corp., 1924 Broadway, Oakland 12, Cal. The material complies with the Underwriters' Laboratories standards for thermoplastic insulated wires for 600-volt service for use in accordance with the 1953 National Electrical Code. Materials cost savings versus equivalent copper wire are claimed.

Vacuum Processing of corrosion resistant alloys promises to improve their durability, researches conducted by Carboley Dept., General Electric Company, Detroit indicate. Information on these and other aspects of the vacuum melting principle are included in Technical Bulletin VM-101 issued by the company.

Unplasticized PVC 3 and 4-inch pipe fittings are now being injection molded on a commercial scale by Tube Turns Plastics, Inc., Louisville, Ky. Included are 90 and 45 degree elbows, tees, couplings and flanges. All Tube Turns fittings from $\frac{1}{2}$ -inch up are available in normal and high impact PVC and in threaded and socket types.

Tapecoat-X, a new coal tar tape made with extra thickness of coal tar to provide double wrap protection from a single wrap is described in a bulletin available from Tapecoat Co., 1523 Lyons St., Evanston, Ill. Application methods which will lower pipe wrapping costs are described and illustrated.

Stainless Steel, nickel and nickel alloy tubing made by J. Bishop & Co., Platinum Works, Stainless Products Div., Malvern, Pa., are described in a new bulletin issued by the company. Hypodermic, capillary and mechanical tubing are produced in standard and special sizes and finishes.

Rust-Oleum Corp., Evanston, Ill., has released a report on an investigation conducted for it by Battelle Memorial Institute. The investigation sought to determine the degree of penetration of fish oil base coatings into rust on rusted steel specimens. Rusted steel coupons cleaned of loose rust were coated with a specially prepared coating in which the natural glycerol component of the coating was replaced with a synthesized glycerol tagged with a Carbon 14 isotope. A reconstituted coating including the radioglycerol was compared with a standard batch of coating by infrared spectrometer and by other tests and found to substantially identical with it. The synthesized coating was then ap-

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CORROSION
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That's our business — corrosion control, writing specifications, running surveys, designing and installing cathodic protection systems of all types . . . a complete turn-key job.

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Cross Pipeline Equipment Co.
858 Wilson Avenue
Newark, New Jersey

Cross-Curran, Ltd.
11102 Jasper Avenue
Edmonton, Alberta
Pipeline Supply Co.
912 West 11th
Houston, Texas

(Continued on Page 88)

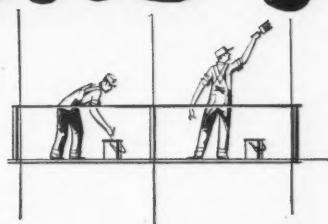
Now there is

Increased plant capacity of 60% now assures quick delivery of enough Parlon (chlorinated rubber) for all your needs! The expanded production facilities were made necessary by the ever-increasing demand for Parlon-based maintenance paints, traffic paints and industrial finishes.

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Indoors or out, on masonry, metal or wood, Parlon-based paints resist the corrosive effects of weather, acid, and alkali; provide longer service at lower, long-term cost. See your paint dealer for details or write direct to Hercules.

for Everyone!



Cellulose Products Department HERCULES POWDER COMPANY 999 King Street, Wilmington 99, Del.

PARLON CHLORINATED RUBBER PAINTS ARE AVAILABLE FROM 400 MANUFACTURERS UNDER THEIR OWN BRAND NAMES

CR55-3(R)

NEW PRODUCTS

(Continued From Page 86)

plied by manufacturer's recommended procedures to rusted steel plates and allowed to dry for the recommended time, two weeks.

The steel plates then were mounted in a special lapping machine so that consecutive 0.5-mil layers could be removed from the coated surface. After each lap the surface was scanned with a radiation counter to determine what proportion of the original coating and vehicle remained in the undisturbed layers of coating and rust. The report issued by Battelle says that the tests showed the fish-oil vehicle penetrated the rust all the way to the metal surface, as proved by the fact that radiation

could be detected in the rust layers immediately adjacent to pure metal. As long as rust remained on the metal surface radiation could be detected.

American Chain and Cable Company's R-P&C Valve Division has redesigned its line of forged steel gate valves. Sizes are from $\frac{1}{4}$ to 2 inches. Principal improvements include stainless steel eyebolts, nuts, followers, redesigned stuffing box, stainless steel wedges and rings.

Dimetcote, a 100 percent inorganic, metallic zinc coating that contains no oils or resins can be applied to existing steel structures by either brush or spray. The bond includes chemical as well as physical adhesion, manufacturers say, producing an interface layer combining the coating and steel. Protection ob-

tained, Amercoat Corp., 4809 Firestone Blvd., South Gate, Cal., claims, is the same as that afforded by galvanizing, plus resistance to salt water. The material also protects the steel surface cathodically. Cost is reported to be less than 6 cents a square foot.

Byron Jackson Company, Los Angeles is now the Byron Jackson Division of Borg-Warner Corp.

Exline Engineering Co., 1636 East 6th St., Tulsa, Okla., is producing Model 155 Constant Rate of Flow Pumps capable of maintaining a constant rate of flow regardless of discharge pressure at pressures up to 10,000 psi.

Reinforced Laminates, Inc., 3040 East Hennepin Ave., Minneapolis 13, Minn., is manufacturing fiberglass reinforced thermosetting plastic pipe in sizes from $\frac{1}{4}$ to 12 inches. Resins used are modified epoxies principally.

High-Tension cables in Consolidated Edison's New York distribution system are now being insulated by a layer of asbestos felt against arcing instead of by a concrete coating as formerly. The asbestos wrappings are tied at intervals with cord made of Fiberglas.

Arco Steel Fabricators, Inc., 12550 Beech Road, Detroit, has been organized to fabricate, design and install process equipment. The new firm was organized by Automotive Rubber Co., Detroit, which also operates Arco Rubber Processors, Inc., Houston and Latex Compounders, Inc., Kalamazoo, Mich.

Rustbond Primer No. 6, a new primer with a drying time of 10 minutes at 85 F can be used over wirebrushed rusted steel, sandblasted and clean-rolled (bright) steel. Dry film thickness of 2 mils at 230 sq. ft. per gallon is claimed by manufacturers, Carboline Co., 331 Thornton Ave., St. Louis 19, Mo. The material has excellent resistance to alkalies and acids and good resistance to solvents. It is compatible with most topcoats. Samples and a new bulletin No. 156 are available on request.

Southwest Fabricating and Welding Co., Houston, a pipe fabricating firm, has been purchased by Walworth Company and will be operated as a division of the company.

Haveg 1810, pure, unplasticized polyvinyl chloride and its uses are described in a new 12-page brochure now available from C. R. Runk, Fabrication Division, Haveg Corp., 900 Greenbank Road, Wilmington 8, Del. Specifications on pipe and fittings, fume ducts and fittings, dampers, weather caps and valves, specially fabricated items and other information are included.

Titanium alloy extrusions are now being fabricated on a production basis by Harvey Aluminum, 19200 S. Western Ave., Torrance, Cal. Sections are being extruded in lengths to 12 feet in several alloys, all being shipped to airframe manufacturers.

Selenized Process Company of Omaha, Neb., has developed a process for treating metal surfaces, especially cooking utensils, which prevents food from adhering to the metal when cooked.

(Continued on Page 90)



"I got the idea from Standard Magnesium's VIBRA-PAK Anodes . . ."

We're not so sure it's cricket to carry your own sod on the golf course. But there ARE times when carrying your own soil can mean quite a saving in time, trouble and expense. That's why every VIBRA-PAK Anode is delivered to you already compacted and centered in backfill, ready to drop in the hole. You get BETTER positioning . . . EASIER installation . . . FASTER installation, every time.

There are several other good reasons for specifying Standard Magnesium VIBRA-PAK Anodes, too. The patented spiral core, for example . . . which really stays put; won't separate from the anode. And, of course, the best reason of all; the magnesium in each VIBRA-PAK Anode is spectrographically analyzed to assure you of greater purity . . . more current per pound.

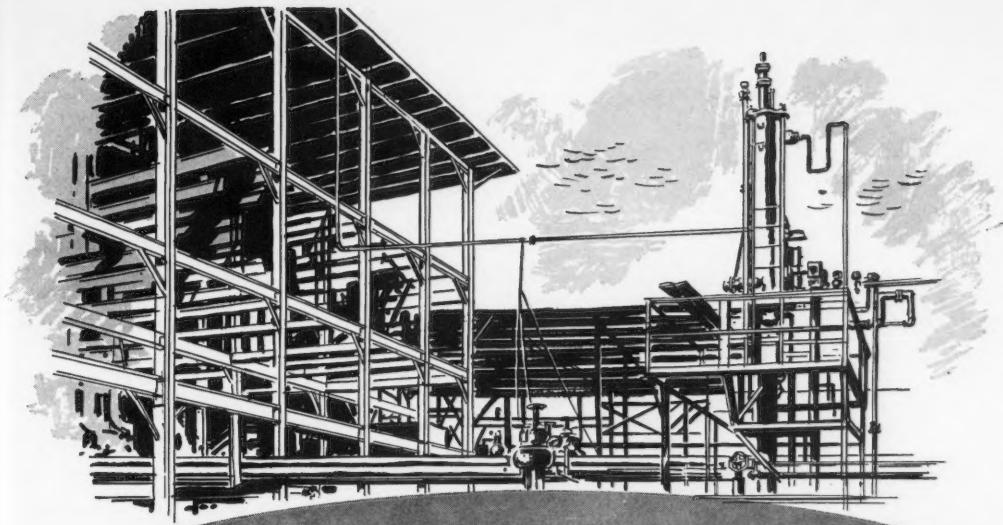
Next time the job calls for dependable Magnesium Anodes to aid in controlling corrosion, specify VIBRA-PAK . . . the "pre-packaged" Anode that carries its own backfill.

For further information, please address all inquiries to P. O. Box 1424-C, Tulsa, Oklahoma

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CORROSION CONTROL

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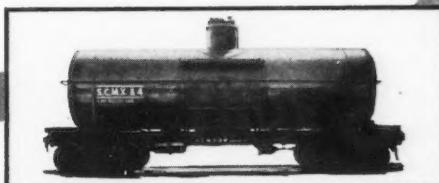
*Protect your
valuable equipment
with COPON—
the revolutionary
coating that takes
unbelievable abuse*

- It gives positive protection against rust and corrosion, also caustics, chemicals, solvents and the destructive action of salt and fresh water.
- It has exceptional tenacity, will adhere to metal surfaces longer and under more difficult conditions than any other coating yet tested.
- It is abrasion-resistant and has proven low erosion rate.
- It has amazing flexibility and elasticity.
- It provides a silky smooth, even surface.
- It is easy to apply by spray, brush or roller coating method.



This tank car is Copon-coated both inside and out to protect it from the ravages of rust and corrosion.

Many boats of varying types and sizes are painted with Copon for positive protection. Here's the toughest test of all!



Copon is manufactured under an exclusive franchise by a select group of companies, strategically located to serve U. S. industry efficiently. Write the company nearest you for details of technical services and specialized product formulation available.

ALLIED PAINT MFG. COMPANY
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ENTERPRISE PAINT MANUFACTURING CO.
2841 South Ashland Ave., Chicago 8, Illinois

COAST PAINT & LACQUER CO.
P. O. Box 1113, Houston 1, Texas

NEW PRODUCTS

(Continued From Page 88)

Food may be cooked without the addition of fats or cooking oils and will not stick to the metal. The treatment also protects the metal against discoloration, pitting and corrosion, manufacturers claim.

720 Series fume scrubbers can be fabricated of Rigidon (glass reinforced plastic), rubber lined steel, carbon steel and other alloys according to manufacturers, Heil Process Equipment Corp., 12901 Elmwood Ave., Cleveland 11, Ohio.

Cobalt-Based Alloys with improved rupture and stretching strength even under 1700 F heat are now being used for turbine blades in jet engines and gas

turbines, according to the Naval Research Laboratory.

Industrial Wastes containing cyanide and chromium compounds can be treated in a new integrated waste treatment system developed by Leslie Lancy, an electroplating specialist and consultant to Fischer & Porter Company, Hatboro, Pa. The system is said to save 75 percent of the cost of other plating waste treatment installations. This and other waste treatment systems are described in Application Bulletin 90-242-10 "Instrumentation for Control of Cyanide and Chrome Waste Treatment Processes," available from the company.

Plastics Research and development laboratories of Debell & Richardson, Inc., Hazzardville, Conn. have been expanded by purchase of 20,000 square feet of

working area and the water power of A. W. Dolge Company.

Aluminum Pig, containing 99.99 percent or more of aluminum is being produced in commercial quantities at the Mead, Washington reduction plant of Kaiser Aluminum & Chemical Corp.

Synthetic Paper, wholly of Nylon fiber is being made commercially by Riegel Paper Corp., 260 Madison Ave., New York 16, N. Y. It is suggested as being useful in packaging and filtering corrosive chemicals.

Teflon-Ceramic seals in dimensions to fit its All-Chem and Rubber-Chem pumps have increased the range of usefulness of the pumps, according to Eco Engineering Co., 12 New York Ave., Newark, N. J.

Comet Model 600, a laboratory aging block that automatically controls temperatures between 100 and 600 F with high precision has been developed by Product Packaging Engineering, 5747 Marilyn Ave., Culver City, Cal.

Ceramic and Cermet research of Marquardt Aircraft Company, Van Nuys, Cal. is being expanded.

Arc-Cast Molybdenum technical and fabricating data are included in a 72-page booklet "Arc-Cast Molybdenum and Its Alloys" published by and available from Director of Technical Information, Climax Molybdenum Company, 500 Fifth Ave., New York 36, N. Y. It is designed to give a complete picture of these alloys for high temperature uses. Molybdenum, with a melting point of about 4750 F and with unusual strength at high temperatures is considered to be a solution to the high-temperature engine problem if its tendency to oxidize rapidly at temperatures over 1000 F can be controlled.

Spray Painting schools will be held November 7-11 and December 5-9 by Binks Manufacturing Co., 3122 Carroll Ave., Chicago 12, Ill.

Pressure Vessels, special fuel atomizers for jet engines and guided missiles are among the many products produced by Combustion Equipment Division of Todd Shipyards Corp., now established at its Houston plant.

Unichrome Crack Free Chromium plating is described in Bulletin CFC-1, available from United Chromium Division, Metal and Thermit Corp., 100 East 42nd St., New York 17, N. Y.

Aluminum Foil production will be increased 32 million pounds annually by expansion of the Davenport, Iowa and Alcoa, Tenn. plants of Aluminum Company of America.

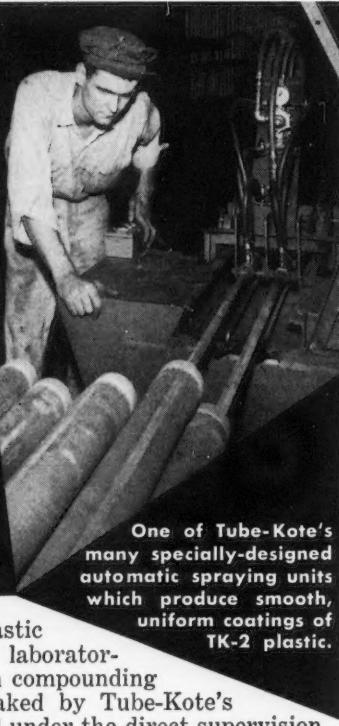
Additional Facilities and acquisition of an additional company are contemplated in an expansion program involving the expenditure of about \$10 million by American-Marietta Company, 101 East Ontario St., Chicago 11, Ill.

Polytrichlorofluoroethylene rod in sizes from $\frac{5}{8}$ -inch OD to 5-inch OD and tubing in wall thicknesses from $\frac{3}{16}$ -inch are being produced by Shamban Engineering.

(Continued on Page 92)

Here's why Tube-Kote's **TK-2** **PLASTIC LININGS**

are considered the most dependable and economical protection against corrosion and paraffin!



One of Tube-Kote's many specially-designed automatic spraying units which produce smooth, uniform coatings of TK-2 plastic.

TK-2 is Tube-Kote's exclusive plastic . . . developed in Tube-Kote laboratories . . . made in Tube-Kote's own compounding department . . . applied and baked by Tube-Kote's specially designed equipment—all under the direct supervision of Tube-Kote chemists and engineers. Their special equipment permits proper pre-conditioning of metal surface . . . assures uniform application of plastics . . . affords an accurate control of baking temperatures.

Another guarantee of high quality is Tube-Kote's 16 years of experience in the development of plastics for lining oil field equipment. They know the problems involved in combating corrosion and paraffin,

and they understand the characteristics and properties plastic linings must have to solve these problems. Their TK-2 has proved so superior it has been applied to more than 12,000,000 feet of oil field pipe!

Pioneers of plastic linings for oil field equipment since 1939. Manufacturers-extruders of plastic pipe for the oil industry.

Write for New 1956 Bulletin on TK-2 Plastic Linings.

Factory-trained field engineers available for consultation in all principal oil areas.



TUBE-KOTE, INC.

P. O. Box 20037 - Houston 25, Texas

Cut maintenance costs... increase pipe life



with proven performance...

Johns-Manville Pipe Protection Materials

On job after job, pipe line men rely on these three Johns-Manville products to fight pipe line corrosion:



Transhield Asbestos Felt

This low cost pipe line protecting wrapper is specially designed to increase pipe life under average soil conditions. It is reinforced with

continuous glassy yarns, parallel spaced on $\frac{1}{4}$ " centers to give tear-free application strength. Made of coal-tar saturated asbestos, it acts as a continuous barrier to shield pipe line enamels from earth loads and soil stresses.



#15 Asbestos Pipe Line Felt

A heavy-duty material particularly suitable for severe soil conditions or where a heavier material than J-M Transhield is desired. Provides long life, toughness, flexibility, resistance to rot, decay, cracking, and impact. J-M #15 Asbestos Felt now protects more than 100,000 miles of oil and gas pipe lines. Widths 2" to 36". Rolls any length desired.



Trantex® Polyvinyl Tape

A widely used coating where ease of application is important... over field-welded joints of mill-wrapped pipe

... for rush coating needs. Pressure-sensitive... sticks to pipe on contact, forming a firm, stable bond. Can be cold-applied by hand or with simple wrapping machines. In rocky soils, an outer wrap of J-M Transhield or J-M #15 Asbestos Pipe Line Felt is recommended.

For further information about Johns-Manville Products for Pipe Line Protection, write to Johns-Manville, Box 60, New York 16, N. Y.; in Canada, Port Credit, Ontario.



JOHNS-MANVILLE
PRODUCTS

PRODUCTS FOR
PIPE LINE PROTECTION

MURDER!

**TNEMEC PRIMER
KILLS RUST AND
CORROSION IN
SALT CARS!**

CASE HISTORY NO. 460. *Victim:* Salt cars used by Leslie Salt Co., Newark, California. *Criminal:* Rust. *Course of Action:* Tnemec primer applied over formerly corroded and rusted sections to protect against salt air and extreme humidity. *Case Closed:* Criminal rust apprehended and killed by TNEMEC.

Learn How TNEMEC Primers Will Kill Rust in Your Plant:

A request on your business letterhead will bring you this useful "Tnemec Specification Booklet." Write today and learn how Tnemec will save money for you by killing and preventing rust in your plant.



TNEMEC COMPANY INC.

139 W. 23rd Ave.
North Kansas City, Mo.

NEW PRODUCTS

(Continued From Page 90)

ing Co., Culver City, Cal. The material is inspected by x-ray to detect cracks, internal strains, bubbles or porosity.

Proximity Meter, an electronic instrument that measures without touching the specimen, can detect a change of one thousandth of one degree Centigrade, variations as minute as one millionth of an inch and other minute quantities. The instrument is described in Technical and Application Manual TM-951-1, "Fielden Proximity Meter Capacitance Gauge" is available from Fielden Instrument Div., Robertshaw-Fulton Controls Co., 2920 North Fourth St., Philadelphia 33, Pa.

Causul Metal Gate Valves, designed for corrosive service are described in a brochure available from Lunkenheimer Co., Box 360, Cincinnati 14, Ohio. Causul metal, from which the valves are made is an austenitic iron containing about 20 percent nickel and substantial percentages of copper, chromium and molybdenum. High resistance to corrosion is claimed for the alloy. The valves are supplied with a variety of high-alloy trims.

Torit Model 219 FM-A cyclone type dust collectors manufactured by Torit Manufacturing Co., 287 Walnut St., St. Paul 2, Minn. contain six throw-away filters. The device filters air back into the room, preventing heat loss in winter.

Six Glass Sealing Alloys, No. 42, No. 52, Sylvania No. 4, AISI Type 446 (27 percent chromium) MT 1010 and OFHC Copper, are described in Data Memorandum No. 15 available from Superior Tube Co., 1729 Germantown Ave., Norristown, Pa.

Nickel Austenitic Ductile Irons, an article by F. G. Sefing, is available in reprint form from Reader Service Section, The International Nickel Co., Inc., New York 5, N. Y.

PERSONALS

H. Carl Wolf, managing director of the American Gas Association and for many years an executive with large gas utilities in Indiana and Georgia died June 26 in a White Plains, N. Y., hospital. He was 63.

William C. Neumann has been named chemical research engineer in the special application department of the Permit Company, 330 West 42nd St., New York 36, N. Y.

Walter C. Rueckel, vice-president of the Henry J. Kaiser Co., Oakland, Cal., has been elected vice-president and general manager of the Engineering and Construction Division of Koppers Co., Inc.

Robert E. Simpson has been appointed sales manager of the Southwest Region and Robert N. Heyman has been made district manager of the Dallas Area for the Libby-Owens-Ford Glass Fibers Co.

Robert H. Stegeman has purchased and is the new president of Barrows Porcelain Enamel Co., Cincinnati, Ohio.

Henry W. Adams has been named sales representative for a territory consisting of Eastern Pennsylvania, Delaware, Virginia and Maryland for The Carbofine Company, St. Louis.

Charles G. Gribble, Jr. has been made Houston branch manager of Metal Goods Corp. He has named **L. L. (Spud) Lehman** as Houston manager of sales.

W. D. Kleppinger has been elected vice-president of General Ceramics Corporation's Chemical Equipment Division. He will have his office at the main plant, Keasbey, N. J.

Wayne Deringer has been appointed associate director of research of A. O. Smith Corp., Milwaukee, Wis. **Forrest W. Nelson** has succeeded Mr. Deringer as director of ceramic research.

Francis Joseph Stokes, 81, died August 1 at Germantown, Pa. hospital after a brief illness. He was president of F. J. Stokes Machine Co., Inc., Philadelphia until 1948.

H. E. Rittenhouse has been named chief engineer of Rockwell Manufacturing Company's Pittsburg Division.

F. Paul Ronca, manager of the Silicon Carbide Product Engineering Department of the Carborundum Company, Niagara Falls, N. Y. has been elected chairman of the technical committee of the Abrasive Grain Association.

Ted Sandelius has been appointed sales engineer to direct the expanded custom coating department of Tube-Kote, Inc., Houston.

E. Von Hombach, a pioneer in the development of stainless steels died August 11 at 62. He was associated for 27 years with The Carpenter Steel Company, Reading, Pa.

Richard T. Crumley has been named sales manager of Toledo Porcelain Enamel Products Co., Toledo, Ohio. Toledo manufactures, among other things, high temperature ceramic coatings for aircraft parts. It is a wholly-owned subsidiary of The Bettinger Corp.

Bernard B. Reinitz retired June 30 after 39 years with The Okonite Co. As chief chemist he was a consultant on high voltage cables and corrosion problems.

Herbert J. French, 62, vice-president of The International Nickel Co., Inc., and assistant vice-president of The International Nickel Co. of Canada, Ltd. died August 17. He was the recipient of many distinguished technical awards for his contributions to the science of metallurgy. He had been with International Nickel since 1929.

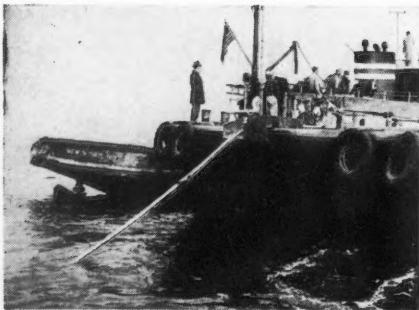
Abstracting services provided by NACE include: the Corrosion Abstracts Section of Corrosion magazine; the Bibliographic Surveys of Corrosion and the NACE Abstract Punch Card Service. Details about any of these can be obtained by writing NACE Central Office, 1061 M & M Bldg., Houston 2, Texas.

An annual index to the abstracts published in the Corrosion Abstracts Section is published in December.



16

**TONS
OF
LEAD
PER
MILE**



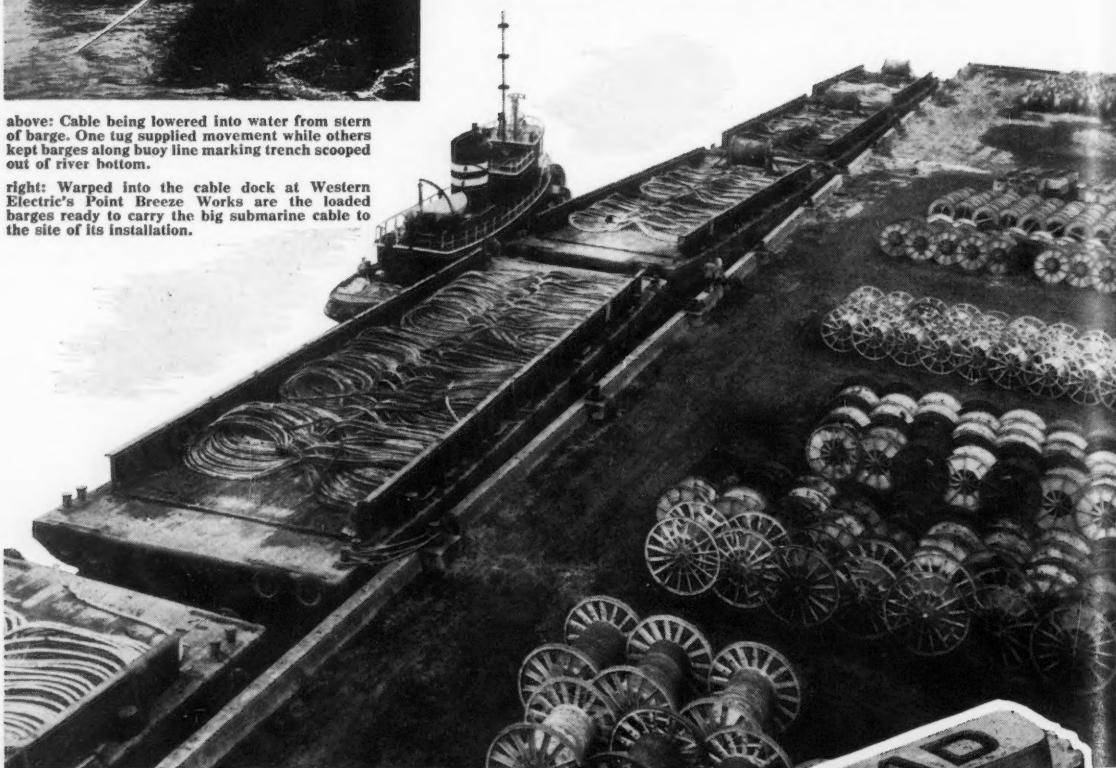
above: Cable being lowered into water from stern of barge. One tug supplied movement while others kept barges along buoy line marking trench scooped out of river bottom.

right: Warped into the cable dock at Western Electric's Point Breeze Works are the loaded barges ready to carry the big submarine cable to the site of its installation.

Three lead-sheathed submarine cables, each 3 miles long were recently laid side-by-side across the Hudson River, forming a main artery for A.T. & T.'s new switching center at White Plains, N.Y. They are the longest and the largest containing coaxial conductors ever made for underwater use. Over 300,000 lbs. of lead were used in manufacturing the 9 miles of king-size cable which is $4\frac{3}{8}$ " thick and weighs $26\frac{1}{2}$ lbs. per ft.

Extruded lead tubing has been used as protective sheathing on electric cable for either voice or power transmission since the late 1800's. The choice of lead for this application is dictated chiefly by a number of highly desirable characteristics inherent in the metal; its pliability facilitates the reeling and unreeling of the cable; its low melting point permits the sheathing to be extruded over the core without damage to the insulation, and it is the only commonly available metal which successfully withstands all of the corrosive influences encountered in the service-life of cable—whether in the air, underground or beneath the sea. This is of particular importance in submarine cables where repair work can be a tremendous undertaking.

Other factors in favor of lead sheathing is that it is malleable, and that convenient lengths of the cable are easily joined with the help of two other lead products, lead sleeves and solder. Finally, when the life of the cable is spent, the lead is easily reclaimed and can be returned to the market for another cycle of service.



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Corrosion Abstracts

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8.10 Group 10	126

1. GENERAL

1.2 Importance

1.2.2, 8.4.3
Measuring Plant Corrosion Costs. V. B. GUTHRIE. *Petroleum Processing*, 9, No. 5, 708-709 (1954) May.

New technique analyses costs proposed by cost study group. Table shows overall and per barrel refining corrosion costs. The figure \$270,000,000 estimates the total refining industry loss. Per bbl. cost is \$0.1125. 8472

1.7 Organized Studies of Corrosion

1.2.1, 5.1
Organising and Operating a Successful Programme of Corrosion Mitigation. M. G. MARKLE. *Corrosion* (News Section), 10, No. 8, 22, 24-25 (1954) Aug.

Author is with Northern Illinois Gas Co., and the object of this article (in which he mentions the application of cathodic protection to hundreds of miles of the company's steel mains) is to indicate how the idea of corrosion mitigation can be sold to all groups (management, technical and operative) in a large organization, so as to obtain their support and cooperation.—BNF. 8896

1.7.1
Corrosion Research: Recent Investigations by the D.S.I.R. Chemical Research Laboratory. *Product Finishing*, 7, No. 7, 92-99 (1954).

A short review of the investigation car-

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BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.
BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.
BNF—Bulletin; British Non-Ferrous Metals Research Association, 81-91 Euston St., London NW 1, England.
CBECC—Centre Belge d'Etude de la Corrosion (CEBELCOR), 17 rue des Drapiers, Brussels, Belgium.
CE—Chemical Engineering, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.
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IIM—Transactions, The Indian Institute of Metals, 23-B, Notaji Subhas Road, P. O. Box 737, Calcutta, India.
INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.
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JSPS—Japan Society for the Promotion of Science, Address: Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1-Chome Nakameguro, Meguro-ku, Tokyo, Japan.
MA—Metallurgical Abstracts, Institute of Metals, London, England, 4 Grosvenor Gardens, London SW 1, England.
MI—Metallurgia Italiana, Associazione Italiana di Metallurgia, Via S. Paolo, 10, Milano, Italia.
MR—Metals Review, American Society of Metals, 7301 Euclid Ave., Cleveland 3, Ohio.
NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.
NBS—National Bureau of Standards, Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.
NSA—Nuclear Science Abstracts, United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.
PDA—Prevention Deterioration Abstracts, National Research Council, 2101 Constitution Ave., Washington 25, D. C.
RM—Revue de Metallurgie, Paris, France, 5 Cite Pigalle, Paris (9e), France.
RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London, Waldegrave Rd, Teddington, Middlesex.
SE—Stahl Und Eisen, Verlag Stahleisen, M. B. H., Dusseldorf, August-Thyssen Str. 1, Postscheck Kolin 4110, (22a) Dusseldorf, Germany.
TIME—Transactions of Institute of Marine Engineers, 85 The Minories, London EC 3, England.
UOP—Universal Oil Products, 310 South Michigan Ave., Chicago, Illinois.
ZDA—Zinc Development Association, 34 Berkeley Square, London W.1.

ried out during 1953 by the corrosion section of the D.S.I.R. Chemical Research Laboratory.—MA. 8862

1.7.1, 4.6.11

Research Center for the Marine Corrosion of Metals. (In Italian). M. RAFFO. *Metallurgia italiana*, 46, special supplement to No. 5, 149-150 (1954) May.

Covers period April 1951 to June 1953.
—BTR. 8920

2. TESTING

2.1 General

2.1.1, 2.2.1

Some Applications of Statistical Methods to Exposure Trials. II. Design of Exposure Tests. H. R. TOUCHIN. *J. Oil*

Colour Chemists Assoc., 37, No. 407, 248-260 (1954) May.

After a brief discussion on the types and sources of errors inherent in exposure trials, descriptions are given of some standard experimental designs, illustrating how the influence of these errors upon the experimental results may be minimized. Some discussion on the number of replicate panels and the use of controls follows. The combining of data from experiments conducted at different times and at different exposure stations is briefly mentioned.—ZDA. 8797

FRIEDBERG. Frank L. Crobaugh Co. *Steel*, 136, No. 5, 76 (1955) Jan. 31.

In spite of limitations such as lack of correlation between test results and actual in-service performance, and lack of standardization of test conditions for organic coatings and agreement on evaluation or meaning of results, salt spray is valuable as accelerated comparison or acceptance test with electrodeposited coatings for specification purposes. Position and support of test panels, control of air pressure in operation of nozzle, and preparation of base metal before application of coating greatly influence test results.—INCO. 8792

2.3.2

The Five Per Cent Salt Spray Test and Its Acetic Acid Modification. WARDLEY D. McMMASTER. Gen. Motors Corp. *ASTM Bull.*, No. 203, 62-69 (1955) Jan.

Development of salt spray test method in ASTM is covered. Studies are presented to show inherent operating problems of 20% salt spray, and their solution by adoption of 5% concentration of salt solution. Method B 117 was unsuited to testing of most plated items, and acetic acid version of 5% revision of Method B 117 is presented as a suitable testing medium for cadmium, zinc, and chromium platings on steel or die-castings, and for anodized aluminum and phosphated aluminum. Acetic acid version appears to be acceptable for all salt spray testing. Tables, graphs, illustrations and 17 references.—INCO. 8757

2.3.2, 5.4.5

Make Sure Your Underground Metal Coatings Do Their Job. L. G. JONES. *Power Eng.*, 59, No. 1, 86-87 (1955) Jan.

Method of testing coatings known as the "salt crock test" is described. Pipe samples with their submerged ends welded closed and outside surfaces coated with materials to be tested are hung suspended in saturated sodium chloride solution in a 5 gal. glazed earthenware crock through a circle of ten holes in the crock's wooden lid. One of the 10 samples is kept uncoated to serve as a standard. Bare top ends of pipe nipples are connected to a multipoint switch, through a milliammeter and four dry cells to a center bare pipe for completion of a direct current circuit through salt solution. Test results are tabulated and discussed. Requirements of a good coating are listed. Some phases of steel water main corrosion are tabulated. Illustrations, tables, 4 references.—INCO. 8903

2.3.4, 2.3.9

The Spectrographic Analysis of Brass and Other Materials by the Porous-Cup Method. L. G. YOUNG, J. M. BERRIMAN AND B. E. J. SPREADBOROUGH. *Analyst*, 79, No. 942, 551-561 (1954).

Details are given of the apparatus and method for the spectrographic determination of zinc in brass using the porous-cup technique. The method has been applied to the determination of magnesium in iron, aluminum in copper, and Al in Al-magnesium alloys, and, using gold as an internal standard, to the analysis of powders, scales, residues, precipitates, and corrosion products.—MA. 8831

2.3.7

Mechanical Properties and Tests. J. B. CAMPBELL. *Materials & Methods Manual No. 106. Materials & Methods*, 40, No. 1, 109-132 (1954) July.

A comprehensive compilation of terms representing the most important mechanical properties and tests of common engineering materials. The glossary is designed to give a brief, easily visualized picture

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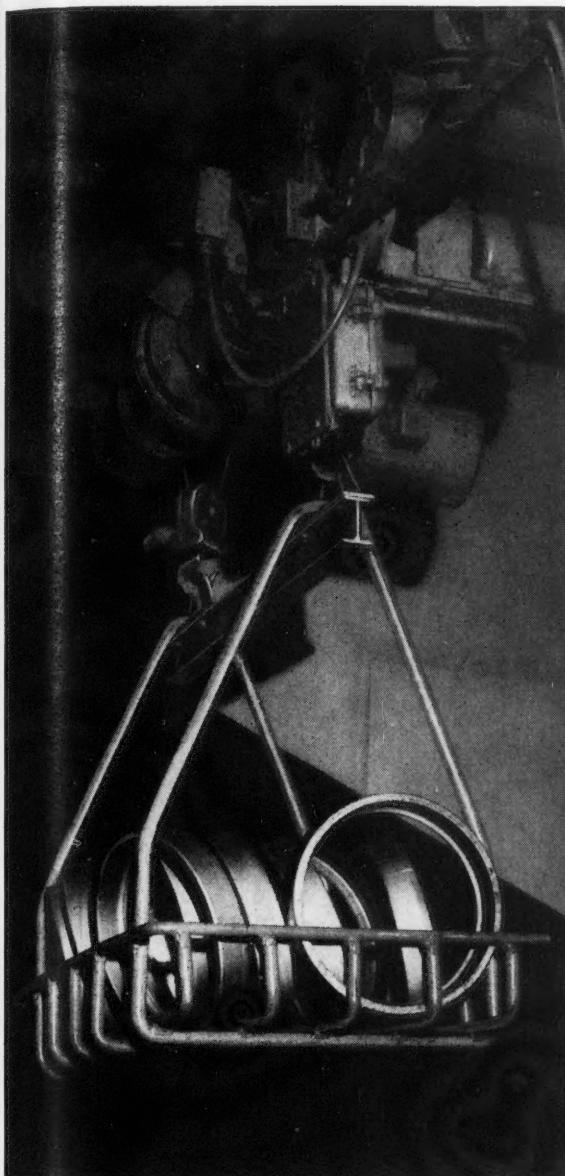
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of the true meaning of each property, namely the test by which it is determined.—INCO. 8916

2.3.7, 2.4.2

An Inexpensive Constant-Load Testing Machine. M. E. CLARK AND O. M. SIDEBOTTOM. University of Illinois. Paper before Am. Soc. Testing Materials, 57th Ann. Mtg., Chicago, June 13-18, 1954. *ASTM Bull.*, No. 203, 69-72 (1955) Jan.

Design and features of an inexpensive testing machine for application and maintenance of constant loads. Performance characteristics indicate that the machine is well suited for maintaining the load constant within small limits of variation over extended periods of time under variable head speeds. Diagram and table.—INCO. 8772

2.3.7, 2.4.3

A Magneto-Inductive Instrument for Thickness Measurement of High Sensitivity and Wide Range. (In German). E. BERTHOLDT. *Metalloberfläche* (Ausgabe A), 8, No. 8, A117-A119 (1954) August.

Instrument for non-magnetic coatings on steel, said to show valid recordings at thickness of 0.25μ , $50-200\mu$, $0.2.2.0$ mm.—BNF. 8849

2.3.7, 3.5.8

Poisson Effect in the Charpy Test. E. HARTBOWER. Am. Soc. Testing Materials Preprint No. 77, June, 1954, 8 pp.

A linear relationship was established between the Poisson effect and energy-to-fracture in pearlitic steel Charpy bars of the V-notch and keyhole types. The relationship was independent of chemical composition, heat treatment and testing temperature.—BNF. 8870

2.3.7, 5.3.2

Study of the Variation in Porosity of Electrolytic Coatings with the Conditions of Electrolysis. (In French). R. AUDUBERT AND M. BONNEVAY. *Compt. rend.*, 238, No. 21, 2083-2084 (1954) May 24.

Two new methods of determining porosity: by the change in potential of an electrodeposited plate specimen in a solution of a salt of the basis metal, and by a radio-isotopic study of the dissolution of the basis metal under these conditions. Applications to chromium, plated on copper, from various baths.—BNF. 8924

2.3.7, 5.4.5

Water Permeability of Paint Films. W. C. G. WHEELER. *Chemistry and Industry*, No. 47, 1441-1442 (1954) Nov. 20.

Simple method for comparing rate of transmission of water through films of different paints. A glass plate is coated with a thin film of a solution of gum arabic and cobalt chloride which turns blue, and paint is spread over the warm plate. After drying for 3 days, plate is immersed in an upright position to $\frac{1}{2}$ its depth in sea water. Number of days taken for gum layer to turn pink is noted; this represents transmission of about 2 milligrams/sq. cm. Film over gum is removed, rinsed, dried and checked with micrometer.—INCO. 8823

2.3.7, 6.2.4, 3.5.8, 3.7.2

Notch-Strength Characteristics of Various Heat-Treated Low-Alloy Steels. G. SACHS AND V. WEISS. Work carried out for International Nickel Co. Syracuse Univ., Jan., 1955, 34+pp.

Program was formulated to develop a test procedure for evaluating the tendency of low alloy steels to brittle behavior in service, and to demonstrate with the aid

of such a test the beneficial effect of nickel additions. New test method, concentric notch-tension test, was developed, which differentiated between different steels and steel conditions, if their strength level exceeded 200,000 psi. Variation of this test offers possibilities for differentiating at lower strength levels. Conclusions are based on concentric notch-tension tests and results of impact tests. Nickel steels investigated were superior to manganese steels under all conditions of heat treating and testing leading to tempered martensite, provided tensile strength exceeded 200,000 psi. Nickel steels were found superior to chromium steels in certain respects. Specimens tested were 3.5% nickel steel (2340), 1.0% chromium-0.025% nickel steel (5140), and 2% manganese-0.098% nickel steel (1340). Tables, graphs and 13 references.—INCO. 8879

2.3.9

Continuous Recording of Chemical or Physical Transformations by Electron Diffraction. (In French). JEAN-JACQUES TRILLAT AND NOBORU TAKAHASHI. *Acta Crystallographica*, 7, No. 1, 15-16 (1954).

A beam of diffracted electrons is incident upon a plane photographic film moving in a direction at right angles to the undeviated electron beam, and the incidence of the diffracted beam upon the film is limited by a narrow slit in a metal plate moved at an appropriate speed by an electrical motor suitably geared. The apparatus has been applied to study: 1) the growth of thin metallic films; 2) changes in the structures of alloys as a function of temperature (for this purpose an alloy film is mounted upon a support capable of being heated to 1000°C and examined by a beam of transmitted electrons); 3) the evolution of alloy phases in the copper-aluminum system in vacuo, more especially to record disorder and structural hardening associated with the presence of CuAl₂. Representative results are given of the evolution of copper-aluminum alloys containing, respectively, 40 and 50% aluminum; and 4) the oxidation of aluminum and its progressive transformation into γ -Al₂O₃. Seventeen references.—MA. 8849

2.3.9, 1.6, 3.2.3, 6.3.6, 3.8.4

Theoretical and Experimental Investigations of the Atomic Phenomena Occurring On and Near the Surfaces of Solids. Part I. Surface Studies of Solids by Total Reflection of X-Rays. Part 2. Structure of Thin Evaporated Copper Films by Total Reflection of X-Rays. L. G. PARRATT. Cornell University. Contract AF-18 (600)-674, Technical Report No. 1, March 15, 1954, 68 pp.

Analysis of the shape of the curve of reflected x-ray intensity vs. glancing angle in the region of total reflection provides a new method of studying certain structural properties of the mirror surface about 10 to several hundred Angstroms deep. Dispersion theory, extended to treat any (small) number of stratified homogeneous media, is used as a basis of interpretation. Curves for evaporated copper on glass are studied as an example. These curves may be explained by assuming that the copper (exposed to atmospheric air at room temperature) has completely oxidized about 150 Å deep. If oxidation is less deep, there probably exists an electron density minimum, perhaps just below an internal oxide seal. This seal, less than about 50 Å, perhaps 25 Å, below the nominal surface plane, would arrest further oxidation of more deeply-lying loose-packed copper crys-

tallites. All measurements to date have been carried out under laboratory atmospheric conditions which do not allow satisfactory separation or control of the physical and chemical variables involved in the surface peculiarities. The method, under more controlled conditions of preparation and treatment of the surface, promises to be useful.—NSA. 8844

2.4 Instrumentation

2.4.3

Correlation of Gamma Radiography and Magnaflux Indications in the Inspection of Large Cast-Steel Connecting Rods. R. L. THOMPSON. Battelle Mem. Inst. *ASTM Bull.*, No. 197, 58-59 (1954) April.

Actual case history of the detection of severe shrinkage cracking in a large steel casting is presented. Correlation between gamma radiography and the magnetic particle method, resulting in greater information upon which an inspector can base his final decision, is given.—INCO. 8816

2.4.3

The Use and Scope of Iridium-192 for the Radiography of Steel. R. HAIMSHAW. *British J. Applied Physics*, 5, 238-243 (1954) July.

Definition obtainable and its importance with different types of flaw. Ranges of thickness of welds and castings on which satisfactory flaw-sensitivity should be obtained. Graphs, tables. Ten references.—MR. 8866

3. CHARACTERISTIC CORROSION PHENOMENA

3.1 General

3.1.1, 1.6

Chemistry Research, 1953. Chemical Research Laboratory. Pamphlet, 1954, 73 pp. Her Majesty's Stationery Office.

A large section of this report (pp. 2, 7-9, 10-19) is devoted to the researches on corrosion, including atmospheric, immersed, underground and microbiological corrosion of a variety of materials. An unusual case of lead cable-sheath corrosion was traced to the products of degradation of the paper insulation by cellulose-decomposing bacteria.

Work covered also includes: search for selenium in waste products and determination of selenium (pp. 19-21); recovery of metals from flash-roasted pyrites cinders (pp. 25-26); separation of metals by ion-exchange resins (pp. 26-27), including copper (p. 38). A list of 26 metals held by the Chemical Research Laboratory for the Pure Metals Committee, with purities, is given (p. 63).—BNF. 8893

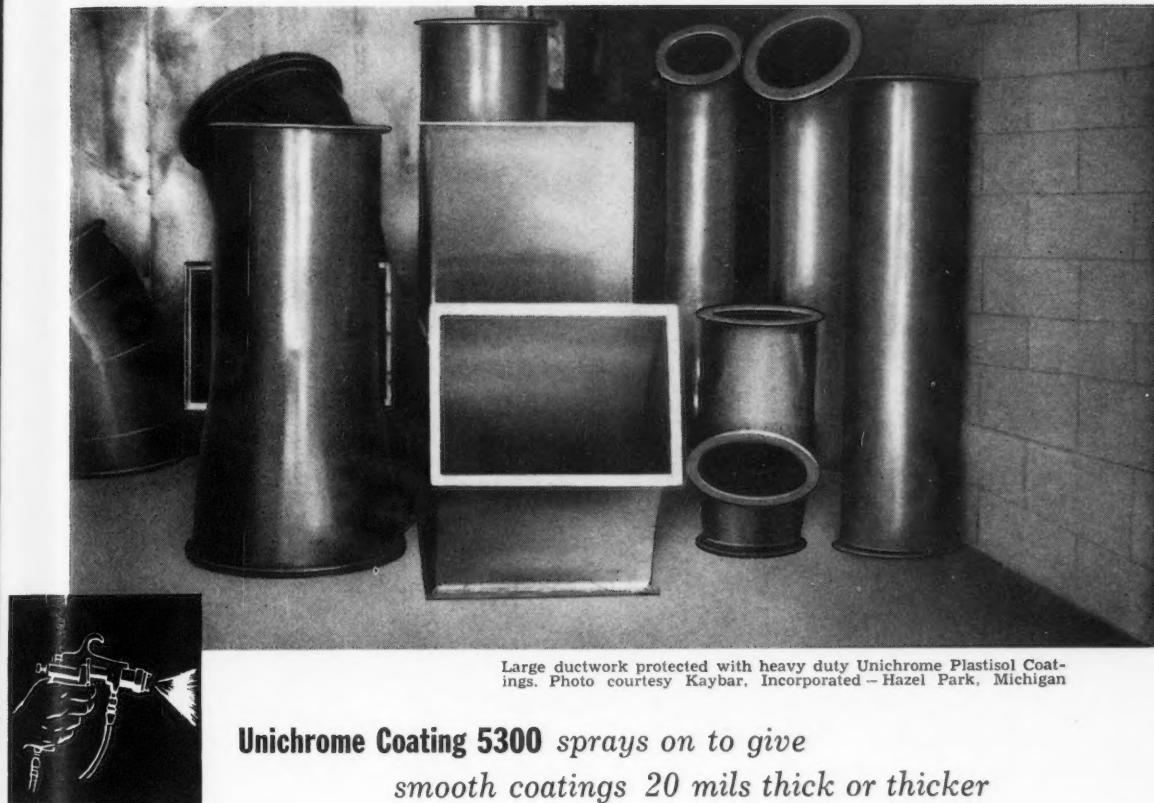
3.2 Forms

3.2.2

Effect of Local Action Currents. H. H. UHLIG (MIT). *Proc. Nat. Acad. Sci. U.S.A.*, 40, No. 5, 276-285 (1954) May.

It is apparent that the calculations for the irreversible behavior of iron must apply in principle to any corrodible metal. Deviation from reversibility is characteristic in particular of the transition metals, which, as a group, are noted for their high values of anodic polarization or anodic over-voltage. It is concluded that the measured value of the iron potential depends on the magnitude of local-action current accompanying corrosion by the

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electrolyte and on the extent of anodic polarization. This factor accounts for the observed dependence of the iron potential on pH. Local-action currents vary with all the causes of varying corrosion rate, including trace impurities in the metal, dissolved oxygen in the electrolyte, and composition and pH of the electrolyte. Equations and 22 references.—INCO. 8858

3.2.2

Graphitization in Steel. A. M. HALL. Battelle Mem. Inst. Materials & Methods, 40, No. 5, 96-99 (1954) Nov.

Definition, formation, effects, and prevention of graphitization. Suggested temperature limits for various steels to avoid serious graphitization are tabulated. The breakage of a steam pipe line near a welded joint at the Springdale station of West Penn Power Co. in Jan., 1943, was the first known failure due to graphitization. Photomicrographs, 10 references. INCO. 8872

3.2.2, 3.4.6

Blistering and Embrittlement of Pressure Vessel Steels by Hydrogen. G. A. NELSON and R. T. EFFINGER. Welding J., 34, No. 1, 12s-21s (1955) January.

At high temperatures and pressures, atomic hydrogen from thermal dissociation causes decarburization and general intergranular cracking. At low temperature, diffusion of atomic hydrogen produced by corrosion leads to blisters and isolated cracks (without decarburization). This is brought about by recombination within the metal to molecular hydrogen, which does not readily diffuse through the metal and accordingly builds up high internal pressures. Precautions to be taken against damage of both of these kinds are outlined for use in design, construction and operation of pressure ves-

sels. Photomicrographs and 9 references.—INCO. 8783

3.2.2, 4.6.10

Filiform Corrosion Products on Iron Immersed in Brine. P. F. THOMPSON and K. F. LOKING. Australia: Dept. of Supply Aero. Res. Labs., Met. Note No. 1, May, 1954. *J. Roy. Aeronaut. Soc.*, 58, 736 (1954) October.

New type of filiform corrosion pustule was observed on steel test specimens immersed in commercial refrigerating brine containing chromate as corrosion inhibitor. Filaments were secondary corrosion products growing from primary hemispherical pustules on metal surface. Mechanism of growth of filaments is discussed.—INCO. 8810

3.2.3, 3.8.4, 6.3.6, 2.3.9

On the Selective Oxidation of an α -Brass Single Crystal. NOBORU TAKAHASHI. *Compt. rend.*, 238, No. 4, 462-463 (1954) Jan. 25.

A single crystal of α -brass was prepared by successive evaporation in vacuo and condensation at 420°C of copper and zinc on a cleaned surface of sodium chloride and the conditions of selective oxidation to cuprous oxide and zinc oxide were studied by electron diffraction. The temperature must not be allowed to fall below 400°C or a single-crystal structure will no longer be obtained. An effect of multiple reflection was observed in the case of zinc oxide.—MA. 8807

3.2.3, 5.3.2

"White Rust." H. BABLIK. *Sheet Metal Inds.*, 31, No. 330, 845-846 (1954) Oct.

Significance of the white corrosion product which forms on many galvanized articles exposed to a humid atmosphere in relation to inspection of galvanized products. Protection against "white rust" can be obtained by giving articles immediately after galvanizing, a 30-second dip in a 0.07 unacidified sodium-bichromate solution at 65°C.—INCO. 8922

UNCKEL. Metal Ind., 85, No. 9, 167-168 (1954) August 27.

Unckel discusses generally the stress-corrosion of copper and aluminum alloys and steel and notes that the tendency to season-cracking in brass is higher with larger grain-sizes and that cold work improves the resistance to cracking. Annealed brass has a higher resistance to cracking below a threshold stress; at high stresses cold-rolled material is better. No absolute cure is known; either the corrosion or the stress must be avoided.—MA. 8811

3.5.9, 3.7.2, 3.2.3

Catastrophic Oxidation of Some Molybdenum-Containing Alloys. S. S. BRENNER. General Electric Co. *J. Electrochem. Soc.*, 102, No. 1, 16-21 (1955) Jan.

When nickel or chromium is added to binary iron-molybdenum alloys, catastrophic oxidation occurs in certain concentration regions. Chromium is more effective than nickel in inducing this rapid type of oxidation. Catastrophic oxidation occurs because of the formation of liquid molybdenum trioxide along the metal-oxide interface. This is preceded by the cracking of the chromium or nickel-containing oxide. Catastrophic oxidation does not occur with alloys containing large amounts of nickel. (auth.)—NSA. 8776

3.5.9, 3.7.2, 3.2.3

Oxidation of Iron-Molybdenum and Nickel-Molybdenum Alloys. S. S. BRENNER. General Electric Co. *J. Electrochem. Soc.*, 102, No. 1, 7-15 (1955) Jan.

Binary alloys of iron and molybdenum (up to 12.5 atomic % molybdenum) and nickel and molybdenum (up to 19.7 at. % molybdenum) do not exhibit "catastrophic oxidation" up to 1000°C either in stationary or in flowing atmospheres. In both systems, molybdenum dioxide and iron molybdate or nickel molybdate are formed in addition to iron oxides or nickel oxide. Molybdenum significantly decreases the oxidation rate of iron by preventing formation of the cation-deficient ferrous oxide normally formed on iron above 570°C. The oxidation rate of nickel, however, is affected only to a small extent. Up to 3 at. % molybdenum the rate is slightly increased by the formation of additional vacancies in the nickel oxide, while beyond 12 at. % the oxidation rate is again decreased owing to the densification of the molybdenum dioxide sub-scale. (auth.)—NSA. 8775

3.5.9, 6.3.6, 6.3.19, 3.2.3, 3.8.4

The Morphology of Zinc Oxide Crystals Formed on the Surface of Brass or Zinc (Heated in Air) at High Temperatures. (In English). RIITSU TAKAGI. *J. Phys. Soc. Japan*, 9, No. 2, 162-168 (1954) March/April.

Electron diffraction and microscopy reveal the presence of thin needle-shaped hexagonal crystals of zinc oxide on the surface of brass or zinc heated in air; the crystal axes are parallel to the (110) direction, in contradistinction to the needle-shaped crystals constituting zinc oxide smoke which have their axes parallel to the (001) direction. On brass the crystals begin to form at ~300°C, and the largest begin to form at ~550-650°C; growth is suppressed at temperatures above 700°C, and no zinc oxide occurs on the surface near the melting point. On zinc (melting point 419°C) the largest crystals are produced at 450-550°C, at which temperatures dendritic crystals with 60° branching, and flat sword-shaped crystals occur. When a brass or zinc surface is consider-

ably distorted or struck with a sharp object similar to that used in the figure, 155, 321 for more than 100 references.—

3.5.9, 6.3.10

Effect of Copper Alloy.

W. D. JENKINS and J. W. JOHNSON. *J. Metals*, 1, 21-36 (1949).

Short time temperatures two 70% ni (Monel). Experiments that discontinuous measurements of both at temperatures. This phenomenon aging at the recrystallization growth at the two alloys a strain, aging, etches, and graphs, photo-

3.5.9, 4.2.2

Arctic Reliability Problems.

Age, 175, No.

Inadequate temperatures cause of failure in Arctic temperatures of welded constructions sensitive structures in ships and land use. Anor, defined to loses heat if conditions, failures. High manganese magnesium, 6 ref-

3.6 Electrical

3.6.6, 6.3.15, Galvanic

nium and Zinc Solutions.

KENAHAN A. Bureau of Min. No. 3, 102-10

Aluminum members of titanium in dilute sulfuric acid presence of particularly alloys are of the immersion period titanium alloys and aluminum and sulfuric acid attack increases. The direct current is always relative values of the same if any, galvanic couples of titan less steel, a sizeable difference in speci-

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ably distorted mechanically, e.g. by being struck with a hammer, plate-shaped zinc oxide crystals showing rotational slip similar to that observed by Wilman [*Nature*, 155, 321 (1950)] occurred on heating for more than 10 hours at 500-600 C. 19 references.—MA. 9067

3.5.9.6.3.10 Effect of Temperature on the Tensile Properties of a Commercial and a High-Purity 70-Percent-Nickel-30-Percent-Copper Alloy. Research Paper No. 2561. W. D. JENKINS, T. G. DIGGES AND C. R. JOHNSON. *J. Res. Natl. Bur. Standards*, 54, No. 1, 21-36 (1955) January.

Short-time tensile tests were made at temperatures ranging from 75-1700 F on two 70% nickel-30% copper alloys (Monel). Experimental evidence showed that discontinuous flow occurred in specimens of both alloys fractured in tension at temperatures ranging from 300-1700 F. This phenomenon was attributed to straining at the lower temperatures and to recrystallization accompanied by grain growth at the higher temperatures. Variations in chemical composition of the two alloys also affected the degree of straining, strength and ductility properties, and fracture characteristics. Tables, graphs, photomicrographs and 10 references.—INCO. 8753

3.5.9.4.2.2 Arctic Regions Pose Tough Metallurgical Problems. F. W. MEYERS, Jr. *Iron Age*, 175, No. 3, 79-82 (1955) Jan. 13.

Inadequacy of ordinary steels for low-temperature use may be the primary cause of failures in equipment built for use in Arctic areas. High transition temperatures of steels, inadequate design for welded construction, and use of notch-sensitive steels have contributed to failures in ships, bridges, and equipment for land use. An intangible "wind-chill" factor, defined as the rate at which an object loses heat if placed outdoors under given conditions, complicates metallurgical failures. High-tensile low-alloy and high-manganese steels, and aluminum and magnesium alloys have been used experimentally with some success. Illustrations, 6 references.—INCO. 8760

3.6 Electrochemical Effects

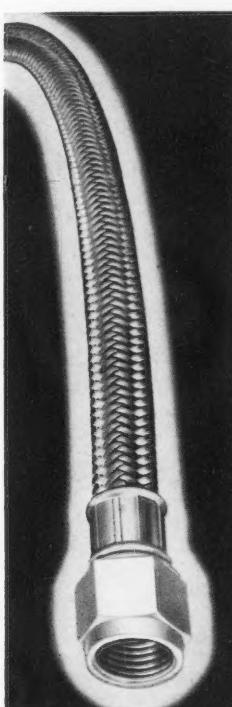
3.6.6, 6.3.15, 6.3.20, 6.2.5, 6.4.2

Galvanic Corrosion Behavior of Titanium and Zirconium in Sulfuric Acid Solutions. DAVID SCHLAIN, CHARLES B. KENAHAN AND DORIS V. STEELE. U. S. Bureau of Mines. *J. Electrochem. Soc.*, 102, No. 3, 102-109 (1955) March.

Aluminum alloys are the anodic members of titanium-aluminum alloy couples in dilute sulfuric acid solutions in the presence of air. In stronger acid solutions, particularly when air is absent, aluminum alloys are anodic only at the beginning of the immersion period. After an induction period titanium becomes anodic. Aluminum alloys are always anodic in zirconium-aluminum alloy couples immersed in sulfuric acid solutions. The rate of galvanic attack increases with the supply of air. The direction of flow of the galvanic current is always in agreement with the relative values for the electrode potentials of the single metal specimens. Little, if any, galvanic corrosion occurs in couples of titanium or zirconium with stainless steel, although there are generally sizeable differences of potential between single specimens of these metals. In solutions in which single specimens of tita-

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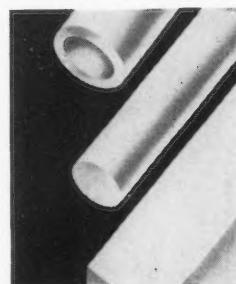
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nium are inert and cathodic with respect to aluminum alloys, contact with these alloys may cause titanium to corrode. This is attributed to activation of titanium surfaces by the hydrogen evolved. Contact with stainless steel in solutions in which titanium is the anodic member of the couple results in marked decreases in corrosion rates of titanium because of anodic polarization of titanium surfaces.

8769

3.6.8, 3.8.4

Reversible Potentials of Cathodic Processes of Metal Corrosion with Oxygen and Hydrogen Depolarization. (In Russian). N. P. ZHUK. *J. Phys. Chem. USSR (Zhur. Fiz. Khim.)*, **28**, No. 1, 188-189 (1954).

It is pointed out that for electrolytes in contact with air the reversible electrode potentials of oxygen and hydrogen ought to be calculated on the basis of partial pressures of 0.21 and 5×10^{-3} atmospheres for oxygen and hydrogen, respectively. Calculation of the potentials at pH 0, 7, and 14 shows that while the correction for oxygen is small (0.010 V.), it is quite substantial for hydrogen (0.186 V.). This means that the discharge of H^+ is thermodynamically possible in electrolytes in contact with air at cathode potentials more positive by 0.186 V., than is commonly accepted.—MA.

8846

3.6.8, 6.5

Polarization Studies of Copper, Nickel, Titanium, and Some Copper and Nickel Alloys in Three Per Cent Sodium Chloride. H. B. BOMBERGER, F. H. BECK AND M. G. FONTANA. *J. Electrochem. Soc.*, **102**, 53-58 (1955) Feb.

Polarization characteristics were determined for some metals and alloys in flowing salt solutions. Relationships between potential and time, potential and applied current, applied current and corrosion rate, and solution velocity and corrosion rate were considered. Copper and brass anodes dissolved readily. Nickel and copper-nickel alloys exhibited anodic polarization. Titanium anodes resisted dissolution by film growth and extensive polarization.

8877

3.7 Metallurgical Effects

3.7.2, 6.2.1

The Metallographic View. Part VI. The Effect of Alloy Content on Microstructures of Slowly Cooled Steels. H. E. BOYER. *Steel Processing*, **41**, No. 1, 34 (1955) Jan.

How the addition of alloying elements such as nickel, chromium and molybdenum affects the basic iron-carbon diagram is discussed and the resulting structures are depicted by photomicrographs. Basic difference in the high-carbon steel and alloy steel structures is mainly in the grain size and in slight increases in pearlite in the alloy steel since less carbon is needed to form pearlite. Photomicrographs.—INCO.

8778

3.7.3

Physical Data on Commercial Silver Solders. K. M. WEIGERT. Goldsmith Bros. Smelting & Refining Co. *Elec. Mfg.*, **54**, No. 3, 143-146 (1954) Sept.

Thermal and mechanical properties of the available commercial grades are tabulated and related to trade designations, ASTM Standards, and Federal and Military Specifications.—INCO.

8818

3.7.3

Less-Corrosive Soldering Fluxes. Tin and Its Uses. No. 30, 9 (1954).

Amine hydrohalides in weak solution or as activators in resin fluxes give off gaseous hydrochloric acid at soldering temperature and leave no ionizable chloride residue which might corrode the metal. For non-electrical applications, where a stronger flux is required, hydrazine is recommended, which contains 70% hydrochloric acid. Care must be taken to wash off any drops of unheated and undecomposed hydrazine hydrochloride flux which may have got on to an adjacent surface.—MA.

8803

3.7.3

Joints Brazed With New Nickel-Base Alloys Exhibit Good Properties. C. V. FOERSTER AND R. C. KOPITUK. *Iron Age*, **175**, No. 8, 79-82 (1955) Feb. 24.

Good mechanical properties, resistance to corrosion, and oxidation and versatility are among chief features of a new series of high-nickel brazing alloys (71.25-93.25% nickel) developed by Coast Metals, Inc. By alloying with base material, they form bond of exceptionally high strength. Most metals having melting points above 1850° can be brazed successfully with new alloys and they are especially suitable for brazing austenitic stainless steels, Nichrome, Inconel and other high-nickel alloys. Alloys are made in rod, powder, wire, strip and washer forms. Table, graphs, illustrations.—INCO.

8790

3.7.3

High-Temperature Alloy Brazing of Thin Materials for Jet Engines. A. S. ROSE AND W. N. LEWIS. I-T-E Circuit Breaker Co. Paper before Am. Welding Soc., 35th Nat. Fall Mtg., Chicago, November 1-5, 1954. *Welding J.*, **34**, No. 1, 30-39 (1955) Jan.

Report is concerned with the use of BNiCr brazing alloy for fabrication of jet engine components, particularly in the assembly of thin sheet materials of stainless and heat-resistant alloys, low-alloy and carbon-steels. These alloys are available commercially under such trade names as Nicobraz and Rexweld 64. Several aspects of the BNiCr properties require consideration in order to enable its successful usage. Relatively wide solidus-liquidus range between 1850-1950 F and the erosive penetration and alloying of the parent materials by the brazing material are important. For production brazing of Inconel and A286, it is necessary to resort to a protective plated layer of nickel or iron which prevents formation of the titanium and aluminum surface oxides and allows brazing alloy to flow freely. Photomicrographs, diagrams and 2 references.—INCO.

8853

3.7.3, 3.5.8

Studies of the Biaxial Fatigue Properties of Pressure Vessel Steels. C. E. BOWMAN AND T. J. DOLAN. University of Illinois. *Welding J.*, **34**, No. 1, 51s-58s (1955) Jan.

Study was made to evaluate the effect of welding, notches, attachments and other fabrication operations upon the resistance of pressure vessel steels to repeated loading. Specimens of $\frac{3}{4}$ -in. plate were subjected to biaxial stresses in a special loading fixture. Data on resistance to repeated loading of unnotched and notched specimens of A225 Grade B and Carillon T-1 steels are reported. In general, the submerged-arc welds and hand welds (ground flush) were stronger than

the plate and did not reduce the fatigue life. Comparison is made between the relative values of plastic fatigue strength of notched and unnotched plates of the four steels investigated, A201, A225, A302 and Carillon T-1, and these are compared with their relative static tensile and yield strengths. Graphs, diagrams, tables, and 7 references.—INCO.

8773

3.7.3, 6.2.2, 4.5.2

The Influence of Condition of the Surface of Iron Upon Rapidity of Corrosion When Buried in Soil. (In German). TIHMOL MARKOVIC. *Werkstoffe u. Korrosion*, **5**, No. 3, 81-83 (1954) March.

Current measurements with rough and smooth iron demonstrated that reversal of current direction, dependent on soil dampness, takes place between narrow limits. Graphs, 6 references.—BTR.

8898

3.7.3, 6.2.5

Sigma Phase in Austenitic Stainless Steel Weldments. O. H. HENRY, M. A. CORDOVA AND G. J. FISCHER. *Welding J.*, **34**, No. 2, 75s-81s (1955) Feb.

Determination of effect of sigma phase on tensile-impact properties of aged austenitic stainless weldments in unnotched and notched conditions. Specific effect of notching weldments in base metal, heat-affected zone or weld was determined. Materials used in the study included AISI Types 304, 310, 321, and 317 austenitic stainless steels, which were subjected to temperatures of 1200, 1350 and 1550 F for 1500 hours. All alloys were tested prior to aging at above temperatures to establish a basis of comparison when in the embrittled state. Effect of a solution anneal of 1950 F after aging at 1550 F was also determined. Tables and graphs.—INCO.

8794

3.7.3, 6.3.15

Strength of Titanium Spotwelded Joints. J. VIGLIONE. *Product Eng.*, **25**, No. 7, 193-196 (1954) July.

The static and fatigue strengths of simple spot welded joints in titanium sheet are compared with those of similar samples of aluminum and stainless steel.—BNF.

8800

3.7.3, 6.4.2

Soldering Aluminium: A Survey of Progress. J. C. BAILEY AND J. A. HIRSCHFIELD. *Research (London)*, **7**, No. 8, 320-326 (1954) Aug.

Soldering methods, typical solder compositions (zinc, tin, and lead alloys), solder embrittlement, effect of alloying additions to solders, joint strength, corrosion and applications.—BNF.

8912

3.7.3, 6.5

How to Weld Some Wrought High Alloys. R. P. CULBERTSON. Haynes Stellite Co. Paper before Am. Welding Soc., Fall Mtg., November, 1954. *Materials & Methods*, **41**, No. 2, 98-102 (1955) Feb.

Procedures are given for welding nickel-molybdenum, nickel-molybdenum-chromium, cobalt-nickel-tungsten, and chromium-nickel-cobalt (N-155) alloys by the metallic arc, inert gas, and submerged melt methods. Particular characteristics of these alloy materials must be taken into account in planning joint design and welding procedures. N-155 alloy is used in cabin hot-air heat exchangers, afterburner sections, and gas turbine engine tail cones, which are exposed to high temperature and oxidation. Tables.—INCO.

8856

3.7.3, 7.7

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Films. R. B. BELSER. *Rev. Sci. Instruments*, 25, No. 2, 180-183 (1954) Feb.

Inium and indium alloys used as solders, without flux, give good adhesion to thin metal films on glass or quartz, since indium also adheres to glass, etc. Used in studying resistivities of thin films and in mounting metal-coated piezo-electric crystals.—BNF. 8910

3.8 Miscellaneous Principles

3.8.2, 3.6.8, 6.2.1

Application of Electrochemistry to Corrosion Investigations. M. POURBAIX. *Werkstoffe u. Korrosion*, 5, 433-440 (1954) November.

Electrochemical equilibrium diagrams, based on thermodynamic data, are constructed and discussed: data on the iron-water system and the behavior of iron and mild steels in bicarbonate solution. Effect of chlorides and phosphates on the corrosion of iron and mild steels in bicarbonate solution in presence and absence of oxygen and prediction of corrosion or immunity from the electrochemical equilibrium diagram are given. Polarization curves and their determination and application of these curves in prediction of corrosion behavior are included. Some data are given on the effect of chlorides on the corrosion behavior of 18/8.—INCO. 8880

3.8.2, 6.3.6, 5.8.3

The Mechanism of the Reaction at a Cu/Cu⁺ Electrode. P. J. HILLSON. *Trans. Faraday Soc.*, 50, Pt. 4, 385-393 (1954).

The exchange reaction that occurs at a Cu/Cu⁺ electrode has been studied by investigating the electrical impedance to a small alternating potential. The rate of the reaction may be calculated from the dependence of the impedance on the frequency of the applied a.c. The reaction has been shown to be very rapid but to occur on only a small fraction of the electrode surface. Surface-active materi-

als were first adsorbed on the quiescent parts of the electrode and then blocked the active sites. The reaction rate on the unpoisoned site was unaffected.—EL. 8892

3.8.3, 6.2.2, 3.8.2

Electrochemical Investigation of the Passivity of Iron. (In Russian). L. V. VANYUKOVA AND B. N. KABANOV. *J. Phys. Chem. USSR (Zhur. Fiz. Khim.)*, 28, No. 6, 1025-1035 (1954) June.

The electrochemical processes occurring in alkaline solutions with anodic polarization on passivated iron electrodes were studied by determining the relation between the electrode potential and the amount of current passed. The electrodes in the form of wire of spectroscopically pure iron were covered before the experiments with a film of $\gamma\text{-Fe}_2\text{O}_3 \sim 50\text{\AA}$, or $\alpha\text{-Fe}_2\text{O}_3 \sim 400\text{\AA}$ thick, by heating in air. The anodic oxidation of the passivated iron was found to consist of two processes: rapid electrochemical adsorption of oxygen and slower deep-reaching oxidation of iron. The addition of Cl⁻ to the alkaline electrolyte slowed down both the adsorption and the oxidation processes, but did not influence the rate of oxygen discharge. The double-layer capacity of the electrodes oxidized by heating in air was ~ 4 times smaller (at 20,000 c./s.) than the capacity of metal free from the oxide layer, owing to the slower adsorption processes on the passivated iron electrodes.—MA. 895

3.8.4, 3.2.3, 6.3.20, 3.4.6

Mechanism of the Reaction of Hydrogen with Zirconium. I. Role of Oxide Films, Pretreatments, and Occluded Gases. E. A. GULBRANSEN AND K. F. ANDREW. *J. Electrochem. Soc.*, 101, 348-353 (1954) July.

Experiments were made on the rate of reaction of high-purity zirconium with pure hydrogen using a sensitive microbalance method and an all glass and

ceramic vacuum system to minimize contamination. The effect of a preliminary vacuum heating cycle on rate of reaction with hydrogen at 150 to 700 C. Samples having the room-temperature oxide present showed only a slow rate of reaction, while samples heated to 700 C for one hour showed a rate of reaction 7700 times as great. Results also showed that the oxide film was effectively removed by heating in a vacuum for one hour at 500 C. A study was made of the thickness and nature of the oxide film. Thus, the film formed in air at room temperature was more resistant to hydrogen attack than thicker oxides formed at higher temperatures. Studies on the effect of small quantities of oxygen and nitrogen in solid solution indicate only minor effects. Results suggest that considerable revision is necessary in concepts of the mechanism of the hydrogen reaction on metals. (auth).—NSA. 8885

3.8.4, 6.3.10, 6.2.5

Enthalpy and Specific Heat of Four Corrosion-Resistant Alloys at High Temperatures. Research Paper No. 2560. T. B. DOUGLAS AND J. L. DEVER. *J. Research Natl. Bur. Standards*, 54, No. 1, 15-19 (1955) Jan.

Specific heats are reported for 80% nickel-20% chromium and two stainless steels (types 347 and 446) from 0-900 C. and for Monel from 0-300 C. Values were calculated from enthalpies measured with drop method and a precision Bunsen ice calorimeter. Relatively small amounts of heat lost by the alloys as they dropped from the furnace to the calorimeter were estimated and corrections were applied therefor. Discontinuities in specific heat were found only in the case of 80% nickel-20% chromium and stainless type 446. Tables, graphs, and 12 references.—INCO. 885

3.8.4, 6.3.10, 6.3.4

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Metallurgical Factors

Resistance of Aluminum Alloys to Weathering by C. J. Walton, D. O. Sprowls and J. A. Nock, Jr., and Resistance of Aluminum Alloys to Contaminated Atmospheres by W. W. Binger, R. H. Wagner and R. H. Brown 50

ering by C. J. Walton, D. O. Sprowls and J. A. Nock, Jr., and Resistance of Aluminum Alloys to Contaminated Atmospheres by W. W. Binger, R. H. Wagner and R. H. Brown 50

Laboratory Studies on the Pitting of Aluminum in Aggressive Waters by T. W. Wright and Hugh P. Godard 50

Salt Spray Testing Bibliography by Lorraine Voight 50

Miscellaneous

Causes of Corrosion in Airplanes and Methods of Prevention by N. H. Simpson 50

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Oxidation of Metals. E. A. GULBRANSEN. *Annals of New York Academy of Sciences (Symp. on Properties of Surfaces)*, **58**, No. 6, 830-842 (1954) Sept. 15.

Calculation of absolute rates of oxidation of nickel and cobalt using classical theory of diffusion, in order to test the mechanism of diffusion by comparing predictions of the theoretical rate expression with experiment. Defects in oxide lattice are discussed and parabolic rate law is derived. The absolute rate theory is applied to the oxidation of nickel and cobalt and results are tabulated. 14 references.—INCO. 8887

4. CORROSIVE ENVIRONMENTS

4.2 Atmospheric

4.2.1, 8.4.5

Transportation of Matter and Radioactivity by Ionized Air Corrosion. W. PRIMAK and L. H. FUCHS. Argonne National Lab., Lemont, Illinois. *Phys. Today*, **7**, 15-16 (1954) Sept.

Reactions involved in the radiation chemistry of the atmosphere are reviewed. Topics discussed include the fixation of nitrogen under conditions of ionization, the corrosion of a metal located in air subjected to intense radiation, the transportation of corrosion products, and the nuisance value of these products.—NSA. 8882

4.3 Chemicals, Inorganic

4.3.2

Metal Materials for Handling Aqueous Hydrofluoric Acid. M. SCHUSSLER. Carbide and Carbon Chem. Co. *Ind & Eng. Chem.*, **47**, No. 1, 133-139 (1955) Jan.

Study of the corrosion resistance of welded or silver-brazed materials such as Monel or copper-nickel in aqueous hydrofluoric acid at concentrations of 48 and 5% under conditions representing probable service conditions, and hydrofluoric acid corrosion tests on Monel weld joints made by the metal arc, shielded inert gas, and oxyacetylene welding processes in order to determine the susceptibility toward stress corrosion cracking of as-welded, stress-relieved and annealed Monel welds. Base materials used in the corrosion tests were cold-rolled and annealed Monel, cold-rolled and annealed copper-nickel (70-30), Illium R, commercially pure lead, and silver (99.99% pure). Nominal compositions of silver-brazing alloys used in making lap joints of Monel for hydrofluoric acid corrosion tests, and corrosion penetration rates are tabulated. Rate and type of attack were determined by measurement of weight loss and by optical examination, and photomicrographs were made at cross-sections. Experimental results are discussed in detail. Precautionary measures in Monel systems for hydrofluoric acid are suggested. Tables, illustrations, photomicrographs, 7 references.—INCO. 8767

4.3.5

Corrosion of Metals In Chlorine at High Temperatures. (In Russian). KH. L. TSEITLIN. *J. Applied Chem. USSR (Zhur. Priklad. Khim.)*, **27**, 953-958 (1954) Sept.

The corrosion of aluminum, carbon steel, copper, stainless steel, and nickel by dry and wet chlorine at varying chlorine addition rates was studied between 260 and 300 C. The data are tabulated. 9 references.—NSA. 8806

4.3.7, 1.3

Hydrogen Peroxide. W. S. Wood. Royal Inst. Chem. Lectures, Monographs and Reports, No. 2, 1954, 35 pp. The Royal Institute of Chemistry, 30 Russell Square, London, W.C. 1.

A general survey (103 references) covering manufacture, stability, compatibility of materials, safety precautions, physical properties, uses. Aluminum is most commonly used for storage and transport. A table shows effect of various metals and non-metals on decomposition of hydrogen peroxide.—BNF. 8833

4.4 Chemicals, Organic

4.4.7, 7.1, 1.7.1

Applicational Research. *Metal Ind. (London)*, **85**, No. 26, 529-531 (1954) December 24.

Research being carried out at Thornton Research Center of Shell Petroleum Co., Ltd. is concerned with testing of fuels and lubricants under actual service conditions with a considerable portion devoted to engine testing. Of greatest interest are problems of wear, friction, corrosion and lubrication. Wear resistance of cast iron cylinder liners and piston rings is discussed. Microstructures of cast iron of good quality and of spheroidal graphite cast iron are shown.—INCO. 8915

4.6 Water and Steam

4.6.2

Treatment of Water for Land Boilers. *British Standard 2486: 1954*, 38 pp. British Standards Institution, 2 Park Street, London, W.1.

Recommended methods of water treatment to ensure relative freedom from scale and some corrosion protection.—BNF. 8902

4.6.4, 5.7.9, 3.3.4

Controlling Slime and Algae Growths. R. B. CONLAN, W. H. & L. D. BETZ CO. *Oil Gas J.*; **53**; Nos. 36, 37, 38, 41, 42, 109, 113, 117, 134, 141 (1955) Jan. 10, Jan. 17, Jan. 24, Feb. 14, Feb. 21.

Slime and algae growths present a problem of considerable importance in industrial cooling-water systems, particularly in the petroleum industry. Slime accumulation aggravates adherence of corrosion products. Pitting may result beneath slime growths even though otherwise effective anti-corrosion treatments are in use. Table lists commercial chemicals, including chlorine, calcium hypochlorite, sodium hypochlorite, sodium pentachlorophenate, 2, 4, 5-sodium trichlorophenate, copper sulfate, bromine, and phenyl mercuric acetate, which are used for slime and algae control. Tables and 5 references.—INCO. 8786

4.6.13, 8.1.4, 1.6

Proceedings of the Eighth Industrial Waste Conference, May 4-6, 1953. *Engineering Bull., Purdue Univ., Extension Series No. 83*, **38**, No. 1, 562 pp. (1954) Jan. Published by Purdue University (Engineering Extension Dept.) Lafayette, Ind., U.S.A.

The following are included in the papers presented at the Conference: "Industrial Waste Treatment Plant for Allison Division of General Motors Corp.", L. I. Couch (pp. 1-9); "Treatment of Municipal and Industrial Wastes by Flootation," R. A. Baum and G. E. Hurst (pp.

10-14); "Operations of Experimental Trickling Filters on Oil-Containing Waste Waters," R. J. Austin, W. F. Meehan and J. D. Stockham (pp. 24-31); "Comparison of Flotation and Sedimentation in Treatment of Industrial Wastes," A. A. Kalinske and R. R. Evans (pp. 64-71); "Systems for the Destruction of Cyanide Wastes at Buick Motor Division," R. J. Brink (pp. 72-85); "The Toxicity of Chromium," R. S. Ingols (pp. 86-95); "Methods for Treating Metal Finishing Wastes," H. S. Kline (pp. 96-104); and "Plating Waste Treatment," C. F. Paulson (pp. 215-221).—BNF. 8911

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.1

New Cathodic Protection Cables. *Wire and Wire Products*, **29**, No. 11, 1373 (1954) November.

Type CP direct burial cables, extremely effective in cathodic protection installation of oil, pipeline, industrial and utility concerns, are marketed by Anaconda Wire and Cable Co.—INCO. 8824

5.2.1

Cathodic Protection: Development of Cathodic Protection in Belgium. A. WEILLER. Paper before Corrosion Group, Society of Chem. Ind., November 13, 1953, London. *Chemistry and Industry*, No. 3, 56-63 (1954).

A historical survey of cathodic protection in Belgium shows how a particular case concerning stray currents and buried pipelines led to co-operative action and the general adoption of cathodic protection. Diagrams, graphs.—MA. 8820

5.2.1, 3.6.9

Avoiding Underground Corrosion. O. C. MUDD. *Shell Pipe Line Corp. Petroleum Refiner*, **33**, No. 6, 172-174 (1954) June.

New techniques in corrosion-mitigation. The substitution of zinc for copper as grounding rods and the addition of insulation to interconnecting ground conductors is discussed. Galvanizing steel results in an exposed surface of zinc, hence it is more practical to galvanize some structural materials to conserve protective current. Installation of electrical current drainage bonds between underground structures is presented. Bonds installed for alleviating damage to nearby unprotected surfaces should not be of low current conductance wire. No. 18 Nichrome wire bonds were destroyed within two years while No. 12 Nichrome wire bonds lasted longer than eight years in the case cited. Diagrams.—INCO. 8871

5.2.1, 3.8.4

Cell Currents and Potentials. ROBERT POPE. *Corrosion*, **11**, No. 4, 59-64 (1955), April.

Cell action is explained to electrical engineers by analogous equivalent circuits and polarization diagrams. Adopting a simplified concept of a theoretical corrosion cell, the criterion of complete cathodic protection is defined. By means of a simple galvanic cell concept and with descriptive polarization diagrams the criteria of minimum cathodic protection under certain relationships of current density between the anode and the cathode are discussed. Effect of anodic and cathodic control, the Pearson null method, similar electrodes with impressed poten-

nickel and iron or their alloys, are tabulated—INCO. 8855

5.9.4, 6.4.2
Iridite No. 14 for Protecting Aluminum Alloys. W. CASTELL. Lockheed Aircraft Corp. *Modern Metals*, 10, No. 10, 42, 44-45 (1954) Nov.

Lockheed Aircraft Corp. has found that complex chromium-chromate films, deposited on aluminum alloys by the Iridite No. 14 process, give excellent corrosion resistance and paint adherence cheaper than chromic acid anodizing. Specifications for basic processing equipment, which was manufactured by Allied Research Products, Inc., are given, and additional equipment is described. Advantages of the process, including flexibility of operations and cost savings, are discussed—INCO. 8926

5.9.4, 8.5
Application of Nitriding to Hot Forging Dies. A. F. SHERYS. Porter Forge & Furnace Inc. *Metal Treating*, 6, No. 1, 14, 16-17 (1955) Jan.-Feb.

Application of surface hardening to forging dies, which contain combinations of chromium, molybdenum and nickel, can definitely improve die life. Surface nitriding produces hard, wear-resistant surface which gives die face ability to resist abrasion, galling, scale adherence, hot erosion, metal-to-metal pickup, and metal sticking and improves flow of metal in dies by reducing external friction and increasing resistance of die impressions to distort or spread. Endurance range and fatigue resistance are increased and hardness is retained at elevated temperatures. Nitrided case can be heated up to 1000°F for long periods of time without softening and up to 1200°F for short periods of time without permanent loss of hardness. Illustrations.—INCO. 8897

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.5, 3.7.2, 3.5.9

Investigation of Wrought Iron-Chromium-Aluminum Alloys for Service at 2200 F. H. A. SALLER, J. T. STACY, AND N. S. EDDY. Battelle Memorial Inst., Contract W-7405-eng-92, June 28, 1954, 46 pp.

The effects of a number of added elements on the workability, oxidation resistance, strength, dimensional stability, bend ductility, hardness, and microstructure of an iron-chromium-aluminum alloy were investigated. The elements added to the base composition singly, or in combination, were beryllium, cerium, copper, magnesium, manganese, molybdenum, niobium, palladium, silicon, silver, tantalum, titanium, tungsten, vanadium, yttrium, and zirconium. The addition of 10 wt. per cent tantalum to the iron-chromium-aluminum base approximately quadrupled the 100-hr. rupture strength at 22 F, in air, without loss in resistance to oxidation. Additions of 5 wt. per cent niobium or 5 wt. per cent tantalum tripled the strength. Other elements, with the exception of palladium were either less effective strengtheners or caused a deterioration in the resistance to oxidation. The best of these alloys approached the strength of Type 310 stainless steel at 2200 F, but were slightly inferior in strength to Iconel. They were more resistant to oxidation than Type 310 stainless steel and equal to or better than

Inconel in this respect. In addition to excellent high-temperature oxidation resistance, the iron-chromium-aluminum alloys possess relatively low thermal neutron absorption cross sections. (auth.)—NSA. 8883

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.6

New Copper Alloys, Particularly Casting Alloys. (In German). E. VADERS. *Z. Metallkunde*, 45, No. 9, 528-533 (1954) September.

Copper-arsenic, copper-antimony and copper-lead-silicon casting alloys: mechanical properties generally similar to those of tin bronzes bearing properties and wear resistance better. Use of copper-lead-silicon alloys (called Ingros bronzes)

for chill-cast fittings, etc., suggested.—BNF. 8815

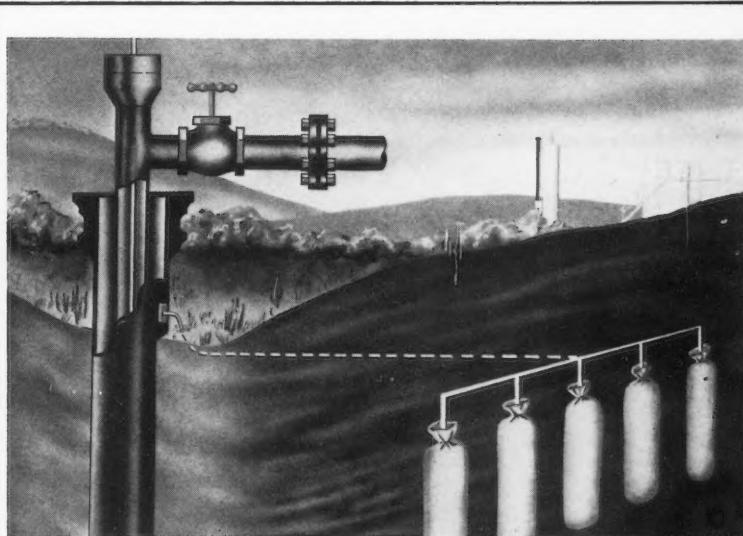
6.3.6, 3.5.8, 4.7

Stress-Cracking of Copper and Brass by Molten Metals. A. R. BAILEY AND R. J. KING. *Bull. Inst. Metals*, 2, No. 8, 105 (1954) April.

Arising from a letter by J. N. Greenwood, authors describe experiments showing that soft copper sheet on immersion in mercurous nitrate solution shows intercrystalline cracking when bent; it loses this brittleness when the mercury in the metal is volatilized by heating. Behavior of brasses in contact with mercury (as recorded in the literature) is discussed.—BNF. 8888

6.3.6, 3.8.4

Anodic Behaviour of Copper in Caustic



Oil Well Casing Protected

An economically feasible method is now being used to protect the casing in oil and gas wells from external corrosion. Either magnesium anodes or rectifiers are used for cathodic protection.

Pioneers in this work are engineers of CSI. Completed last month are CSI installations on 100 wells for three major oil companies. Anodes are used on some of these wells, rectifiers on others.

The latest procedures involve the plotting of polarization curves based on surface measurements. CSI engineers have developed special instruments for these surface measurements. The polarization curves are used to determine the current required for protection.

CSI engineers then design the most economical installation . . . using either anodes or rectifiers . . . depending primarily on soil conditions. Of special interest in this connection is Galvomag, The Dow Chemical Company's new high-potential anode. This anode seems especially suited to casing protection when applied in the new special sizes and shapes now available.

CSI engineers will be glad to work with you on programs to protect your wells. They offer expert consulting, engineering, design and installation services . . . also a complete line of brand-name cathodic protection equipment and supplies. Call or write today for competitive estimates or quotations.



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Soda Solutions. J. S. HALLIDAY. *Trans. Faraday Soc.*, **50**, No. 2, 171-178 (1954) Feb.

Composition of films formed, examined electrometrically and by electron diffraction. Influence of concentration, current density and stirring.—BNF.

9098

6.3.6, 6.3.8, 1.1

Analysis of Metallic Copper and Lead Objects Found in the Roman Wreck "Grand Congloue." ADRIENNE WEIL. *Rev. Met.*, **51**, No. 7, 459-466 (1954) July.

Weil describes the spectrographic and X-ray analysis of lead plates studded with copper nails, recovered from the Mediterranean and dated ~200 B.C. Although these isolated analyses do not enable the exact date or geographical origins of the objects to be determined, they provide reference marks for future work. The analysis of an intact nail under the best conditions gave indications of metal used by the Romans in the third century B.C. and the composition suggested a Cypriot origin. X-ray and micro-examination showed that an object made 2000 years ago retained its initial work-hardening. The lead, as also the copper, showed a high degree of purity. Conclusions about corrosion depend on whether the results of spectrographical analysis or of phase analysis by X-ray diffraction are considered: in the first case it is unwise to trust the analysis of the elements unless there are standards of comparison.—MA.

8817

6.3.8, 3.6.8

On the Overvoltage of Lead Anode and Film-Formation on Lead. S. MIYAKE. *J. Japan Inst. Metals*, **18**, No. 10, 548-552 (1954) Oct.

The overvoltage of lead anode was studied in relation to the electrolytic corrosion of buried cable sheath. At the current densities 1-1000 μ A/cm², the overvoltages were measured in 0.1 N sodium sulfate solutions, then the step-wise potential rise and the increase of resistance polarization at lower potential were observed: a linear relation between overvoltage and log-current density was not observed, but in the case of the experiment with an electrode covered with lead peroxide, prepared by electrolysis in high current density, a linear relation was obtained. The total charge carried through unit area of anode was nearly constant for each arrest of potentials. The films of first arrest were highly resistive, and their thickness was about 1100 Å for low current densities. The second arrest corresponded to the growth of very low resistive films of lead peroxide, and oxygen evolved steadily at the third arrest. For high current densities, the total thickness of films was about 1400 Å.—JSPS.

$$\text{expressed by the equations } E_{\text{m}} = \frac{0.35}{0.40} - 0.45 \text{ pH and } E_w = \frac{0.28}{0.33} - 0.45 \text{ pH.}$$

Molybdenum and tungsten approximate the metallic electrodes with a large shift in the fixed potential to the positive side. Tungsten occupies an intermediate position between the potentials of metallic and nonmetallic electrodes. The electrochemical behavior of molybdenum and tungsten in 20 different electrolytes follows the curve $E_{\text{lg}} N$. The main influence on the potential of molybdenum and tungsten is exerted by basic solutions. This dependence is caused by the change in the pH of the solution because of hydrolysis or dissociation of the electrolyte, formation of complex ions, or passivation of the surface by the action of oxidizing agents. Quantitative tests were made of the corrosion resistance of molybdenum and tungsten by gravimetric and volumetric methods. A comparison of the measured corrosion loss with the quantity calculated by the volume of absorbed oxygen shows good agreement between the two if it is assumed the molybdenum and tungsten are oxidized to molybdenum trioxide and tungsten dioxide. (tr-auth).—NSA.

6.3.10, 3.8.3
Incidences of Passivity in Nickel. (In German). K. HAUFFE AND I. PFEIFFER. *Z. Metallkunde*, **45**, No. 9, 554-562 (1954) Sept.

Commentary review of literature, followed by data from tests on oxide films producing passivity in nickel. Mechanism of formation of protective film, electrochemical behavior of nickel oxide layers and effects of bromine ions on passivation are discussed. Tests in 0.1 N sulfuric acid on oxidized and bright nickel with and without additions of potassium bromide were made. Formation and disappearance of protective film was demonstrated according to Mott-Cabrer theory. Results indicate that nickel sheet with protective layer of porous-free nickel oxide is not resistant to halogen ions. Resistance of a "residual" passive film, noted after anodic current had been cut off, was tested in 0.1 N sulfuric acid.—INCO.

6.3.9, 5.3.4
Coatings on Molybdenum. W. BECK. Syracuse University, Paper before Electrochem. Soc. *Metal Ind.*, **86**, No. 3, 43-46 (1955) Jan. 21.

Deposition of aluminum, silicon and

boron coatings on molybdenum from liquid phase. Liquid is a fused salt bath, and atoms of metal or element to be coated are produced by ionic discharge on a molybdenum cathode. Pre-treatment of specimens, various types of fused salt baths used for production of coatings, electric conditions for deposition, and cleaning of coated molybdenum surface are considered. Properties of coatings are described and results of microscopic examination of structure, and of high temperature oxidation and other tests are given. Graphs, table, photomicrographs, 4 references.—INCO.

Electrodes. I. Thickness and Current Efficiency of Formation, II. (Electrostatic) Field and Ionic Current During Formation. III. Photo (-Conduction and -Voltaic) Effects. L. YOUNG. *Trans. Faraday Soc.*, **50**, No. 2, 153-159; 159-164; 164-171 (1954).

Part I. Methods of determining the thickness of tantalum oxide films, formed on tantalum electrodes by anodic polarization, and ranging in thickness from a few tens to several thousand Å. are described and discussed. Three methods are available, utilizing respectively: 1) capacity measurements; 2) interference colors; and 3) determination of the charge required to form the film. The third method demands a knowledge of the current efficiency of the film-forming process; this approaches 100% as the current density is increased. 13 references.

Part II. The ionic film-forming current density, i , flowing through the oxide during growth is controlled by the electrostatic field, F , in the oxide, according to the relation $i = \alpha \exp \beta F$. Values of α and β are discussed in relation to the theories of Mott [Cabrera and Mott, Rep. Progress Physics, **12**, 163 (1948-1949)] and of Verwey [Physica **2**, 1059 (1935)]. 9 references.

Part III. Photo-conduction and a related photovoltaic (Becquerel) effect exhibited by the films in ultra-violet light are discussed. The photocurrent increases rapidly with thickness up to a few hundred Å, and then remains constant. A photocurrent was found with soft X-rays. 12 references.—MA.

8839

6.3.14, 1.6

The Properties of Tin. Brochure, March, 1954, 55 pp. Tin Research Institute, Fraser Road, Greenford, Middlesex.

This is a revision of the 1937 edition. The values of the various constants have been critically selected from the available information, in some cases by discussion with authorities in the various fields. Includes atomic and nuclear properties, line spectra; X-ray data; crystallography; electrical, magnetic, thermal and mechanical properties; density; solidification shrinkage; viscosity; surface tension; diffusion coefficient; velocity of sound. Data refer to 99.99% tin.—BNF.

8801

6.3.14, 5.3.2, 2.3.9

Metallography of Tin, Tin Alloys, and Tin Coating on Steel. (In Czech). JOSEF TEINDL. *Hutnické Listy*, **9**, No. 2, 95-98 (1954) Feb.

New ways of cleaning, coating, polishing, and etching. Methods for metallographic research of tin layers on steel. Micrographs, diagrams. 14 references.—BTR.

8848

6.3.15, 3.2.2, 3.5.9

Protection of Titanium Metal Against Embrittlement. H. R. TOLER, JR. Am. Terra Cotta Corp. *Bull. Am. Ceram. Soc.*, **34**, No. 1, 4-8, (1955) Jan.

Rates of embrittlement for commercially pure titanium in atmospheres of hydrogen, oxygen, nitrogen, and air were studied at 1700 F. Embrittlement at elevated temperatures is attributed to absorption of small amounts of gases from atmosphere and results in loss of impact resistance. Results indicate that hydrogen was the major source of embrittlement, and that impact resistance was considerably reduced by presence of moisture in either nitrogen or air. Rates of embrittlement of samples of titanium coated with 5 ceramic-type coatings; and

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Tygon "ATD" Hot Spray Paint builds a film thickness of 3 mils or more at a single pass—5 mils or more in two coats—a film thickness that would require six or more coats of conventional cold spray vinyl paints. Adhesion is better. Film continuity (because of the thicker and denser film) is immeasurably improved. And, of course, the proven corrosion-resistance of Tygon Paint is in no way impaired.

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Tygon "ATD" Hot Spray Paint is heated in a conventional hot spray heater to a temperature of approximately 160°F. At this temperature, the viscous Tygon "ATD" Hot Spray Paint becomes fluid. Heat does the work of thinners. As the hot paint leaves the gun, the solvents in the paint evaporate, and a high solids content, 3 mil thick protective coating is deposited on the target. Because most of the solvent has evaporated before the paint hits the target, the coating dries quickly. The finish is excellent, without sags or runs. The film is dense, free from pin holes, and resistant to a wider range of corrosives than any conventional protective coating made.

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DENSITY

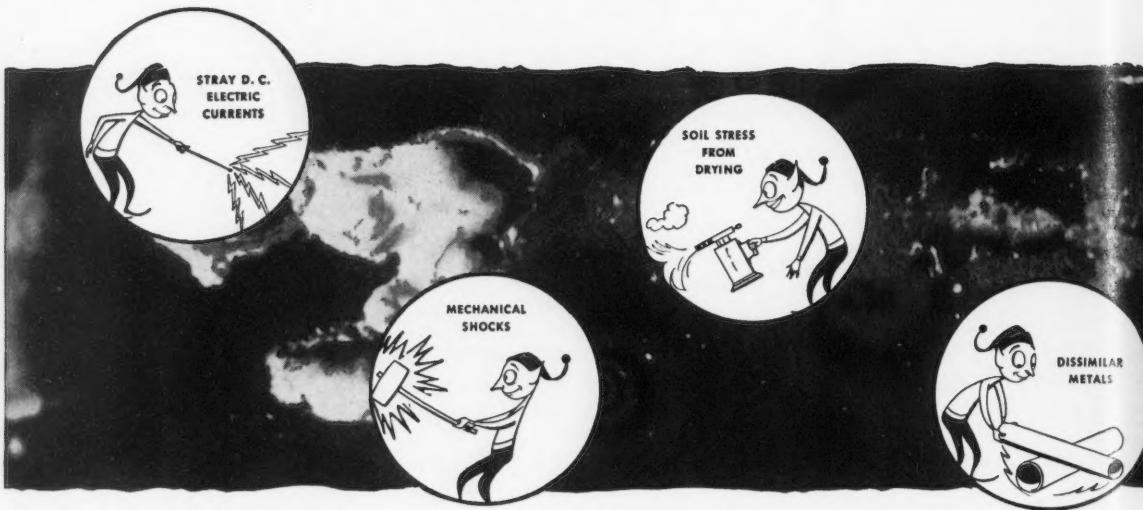


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6 DRESSER PRODUCTS TO OVERCOME THESE MAJOR CAUSES



Gas Men Seek Improved Insulating Methods ... Help Develop Dresser Insulating Products

Whenever utility men get together, corrosion almost always heads the list for discussion—how to best protect their company's huge investment in underground piping. Satisfied that insulated pipe effectively resists corrosion, they are naturally interested in talking over improved insulating methods, new insulating applications.

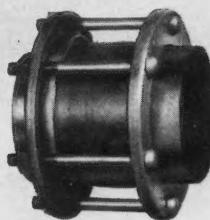
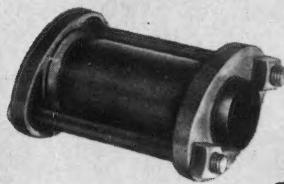
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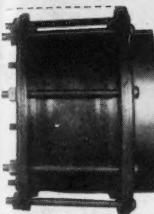
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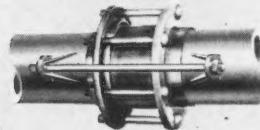
This new insulating connector is made to order for setting gas meters and regulators—a virtually tamper-proof fitting which resists pull-out from the unusual strains often put on service line piping.

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0.001 in. layer of electroplated nickel were tested and it was found that a vacuum-processed ceramic coating retarded embrittlement approximately threefold at 1500 F. Comparative properties of titanium with magnesium, aluminum, stainless steel, and iron, coating compositions, and experimental results are tabulated. Illustrations, graphs, 16 references.—INCO. 8759

6.3.15, 4.3.2, 2.3.4

Corrosion Resistance of Titanium in Acids. W. W. HARPLE. Allegheny Ludlum Steel Corp. *Materials & Methods*, 40, No. 5, 106-108 (1954) Nov.

Discussion of corrosion resistance of titanium in hydrochloric acid and sulfuric acid. Testing procedure, and the effect of additions to the acids are described. Charts show how corrosion rates in hydrochloric and sulfuric acid are influenced by temperature and concentration.—INCO. 8868

6.3.15, 4.7

Corrosion of Titanium in Fused Chlorides—Formation of Pyrosols. C. B. GILL, M. E. STRAUMANIS AND A. W. SCHLECHTEN. Univ. of Missouri. Paper before Electrochem. Soc., Chicago, May 2-6, 1954. *J. Electrochem. Soc.*, 102, No. 1, 42-45 (1955) Jan.

Most severe corrosion of titanium by molten alkali chlorides in presence of air occurred in molten sodium-chloride-sodium fluoride mixtures; samples disintegrated completely at 850 C in less than three hours. Progressively less corrosion occurred in potassium chloride, sodium chloride, and lithium chloride melts. Salt fumes were more corrosive than molten salts because of better access of oxygen to titanium surface. Chief corrosion products were a dispersion of metallic titanium in the molten salt (pyrosols), mixed with titanium oxides. Corrosion rate data are tabulated. 11 references.—INCO. 8791

6.3.17, 3.8.4, 3.5.9, 3.2.3

Oriented Dioxide Films on Uranium. J. T. WABER AND J. A. O'ROURKE. Los Alamos Scientific Lab. U.S. Atomic Energy Comm. Pubn., (AECD-3636); July 6, 1954, Decl. July 22, 1954; 15 pp.

The formation of oriented layers of uranium dioxide on uranium was studied in the temperature range 300 to 1000 C and at water pressures below 25 mm. Hg. High degrees of orientation are formed only when the pressure exceeds about 0.8 mm. Hg. The (110) planes are formed parallel to the metal surface. In vacua the principal orientation of the dioxide is with the (100) planes parallel to the surface, but by further oxidizing the sample in water vapor, the (110) orientation is developed. A preliminary investigation of the rate law indicates that a logarithmic law is obeyed.—NSA. 9065

6.3.19, 1.4, 5.9.4

Chemical Colour Finishing for Zinc. Pamphlet, August, 1954, 13 pp. Zinc Development Assoc., Lincoln House, Turl Street, Oxford.

A selective bibliography of about 80 references arranged under the headings: color finishes, phosphate treatments, general finishes, patents concerned with chemical dip finishes, proprietary chemical dip finishes, and other reference of possible interest.—BNF. 8850

6.3.20

Give Corrosion a Run for Your Money. Steel, 136, No. 4, 74-75 (1955) Jan. 24.

Zirconium has extremely good corro-

sion resistance, particularly to alkalies, sulfuric acid, nitric acid, hydrochloric acid, and phosphoric acid. Since it can be fabricated by casting, forging, rolling, drawing, extruding and welding, it is offered in many shapes, and is used in valve parts, pumps, meters, electronic-tube components, and many other applications where a small quantity of highly-resistant material is needed. Illustrations.—INCO. 8755

6.3.20, 3.4.8, 3.8.4, 3.6.8

Studies on the Anodic Polarization of Zirconium and Zirconium Alloys. MARIO MARAGHINI, GEORGE B. ADAMS, JR., AND PIERRE VAN RYSELBERGHE. *J. Electrochem. Soc.*, 101, No. 8, 400-409 (1954) Aug.

The anodic polarization of zirconium and some of its alloys was studied in several different aqueous electrolytes. In chloride solutions corrosion potentials below that of oxygen evolution were established, but the addition of NO_3^- in the ratio of 3:5 to Cl^- brings the potential above that of oxygen evolution. Formation of the oxide film along the three portions of the potential/time curve (initial rapid increase, evolution of oxygen at practically constant potential, final rapid increase) was studied in detail and quantitative information about local currents and the efficiency of the film-building process was obtained. 7 references.—MA. 8917

6.3.20, 3.6.8

The Electrochemical Polarization of Zirconium in Neutral Salt Solutions. NORMAN HACKERMAN AND OLIN B. CECIL. *J. Electrochemical Society*, 101, 419-425 (1954) August.

Cathodic and anodic polarization curves in neutral sodium chloride at constant current densities between 3.5×10^{-8} and 3.5×10^{-3} amp. per sq. cm. Graphs. Seven references.—BTR. 8844

6.3.20, 3.6.8, 3.8.4

The Electrochemical Polarization of Zirconium in Distilled Water. NORMAN HACKERMAN AND OTTO L. WILLBANKS, JR. University of Texas, Contract Nonr-375 (02), April 23, 1954, 27 pp.

The cathodic polarization curve for zirconium in air-saturated distilled water at 40 C was determined in the current-density range 3.0×10^{-7} to 1.0×10^{-3} amp/cm². At low current densities the reaction was the reduction of dissolved molecular oxygen to hydroxyl ions, its limiting diffusion current being about 5×10^{-6} amp/cm². The formation of a zirconium hydride film was the reaction proposed to explain a plateau in the curve which had a constant potential of -0.30 v vs. standard calomel electrode and a limiting current of 1.0×10^{-4} amp/cm². X-ray diffraction data, time-potential curves, observations, and other evidences substantiated this possibility. Above 1.0×10^{-4} amp/cm² hydrogen evolution occurred, and the curve followed a Tafel relationship, the slope being -0.14 v. The hydrogen overvoltage at 1.0 ma/cm² was 0.75 v. The open-circuit potential of zirconium in air-saturated distilled water at 40 C was determined to be +0.16 v vs. standard calomel electrode. The anodic polarization curve for zirconium in air-saturated distilled water at 40 C was determined in the current-density range from 1.0×10^{-5} to 3.0×10^{-3} amp/cm². The potential rose in a linear fashion with the logarithm of current density, the slope being 0.07 v. A small amount of corrosion increased with temperature was observed but not explained. (auth).—NSA. 8841

6.3.20, 3.8.4, 3.2.3, 3.5.9

Kinetics of the High Temperature Oxidation of Zirconium. JACK BELLE AND M. W. MALLETT. Battelle Memorial Inst. *J. Electrochem. Soc.*, 101, 339-342 (1954) July.

The rate of oxidation of high-purity zirconium was determined for the temperature range of 575 to 950 C at 1 atm. pressure. Data can be fitted to a cubic law, and the rate constant in $(\text{ml}/\text{cm}^2)^2$ law, and the rate constant in $(\text{ml}/\text{cm}^2)^2/\text{sec}$ has been calculated to be $k = 3.9 \times 10^8 \exp(-47,200/RT)$, where $47,200 \pm 1,000$ cal/mole is the activation energy for the reaction. (auth).—NSA. 8890

6.3.20, 3.8.4, 3.2.3

Kinetics of the Reaction of Hydrogen with Zirconium. JACK BELLE, B. B. CLELAND, AND M. W. MALLETT. Battelle Memorial Inst. *J. Electrochem. Soc.*, 101, 211-214 (1954) May.

The rate of reaction of hydrogen with high-purity zirconium was determined for the temperature range of 250 to 425 C at 1 atm. pressure. The reaction was found to follow a parabolic law, and the parabolic rate constant in $(\text{ml}/\text{cm}^2)^2$ per second was calculated to be $k = 2.3 \times 10^8 \exp(-17,200/RT)$, where $17,200 \pm 200$ cal/mole is the activation energy for the reaction. (auth).—NSA. 8886

6.4 Non-Ferrous Metals and Alloys—Light

6.4.2

Aluminum-Base Copper-Cadmium Alloys. E. A. G. LIDDARD. *Product Eng.*, 26, No. 1, 192-196 (1955) January.

New aluminum-base copper-cadmium alloys can be easily worked, will withstand greater reduction than most aluminum alloys, have good hot working characteristics, and offer increased production rates at lower costs through less critical intermediate heat treatment. Table shows typical tensile strength and impact properties and recommended composition is given as follows:

4.8-5.4% copper, 0.1-0.15% cadmium, < 0.25% silicon, < 0.3% iron, 0.3-0.8% manganese, 0.2% titanium, < 0.10% magnesium, < 0.005% tin, < 0.05% lead, < 0.05% zinc, < 0.05% nickel and < 0.02% chromium.

Casting, forging, extruding, rolling and tube making, pressing and deep drawing, welding, machining, heat treatment, influence of cold work in the solution heat treated condition, corrosion and stress corrosion and applications are covered briefly. Graphs.—INCO. 8761

6.4.2, 1.6, 8.8.1

Process Industries Applications of Alcoa Aluminum. 1955, 80 pp. Aluminum Company of America, Pittsburgh, Pennsylvania. Gratis.

A self-indexing, illustrated pamphlet describing the uses, assets and limitations of aluminum and its alloys in the process industries. It is divided into three parts: 1.) Process Industries Applications. Typical uses are illustrated. Advantages are given and a table of the principal features and uses of the principal wrought and cast Alcoa alloys together with an index of the forms in which they are available is included. Some of the anti-corrosive advantages are listed. 2.) A Service Dictionary. Briefly describes the performance of aluminum exposed to various materials arranged alphabetically. This

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<input type="checkbox"/> valves	<input type="checkbox"/> cone blenders
<input type="checkbox"/> flowmeters	<input type="checkbox"/> hoppers
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Other applications (please list) _____

section includes flow charts of basic process layouts with indications where aluminum may be used. Text is keyed to the flow charts. 3.) Design of Process Equipment. Devoted to mechanical considerations, process piping, corrosion considerations, clad products, cleaning methods, inhibitors, coatings, cathodic protection of and by aluminum and numerous technical reference tables. Illustrations of good and bad design are given. 8847

6.4.2, 2.3.4

Reproducibility of 480°F. Static Aqueous Corrosion of Pure Aluminum. P. O. STROM, L. M. LITZ, AND M. H. BOYER Livermore Research Lab., Calif. Research and Development Co., Contract AT (11-1)-74, March, 1954, 11 pp.

Multiple samples of Baker and Adams reagent-grade aluminum were corroded in 480 F distilled water for periods up to 572 hours to check the reproducibility of corrosion rates on aluminum. For the majority of time intervals, reproducible static aqueous aluminum corrosion data were obtained; however, in some cases, the breakdown of the protective film on the aluminum resulted in an accelerated attack on the metal and led to less reproducible data. Film eruptions occurred on specimens which suffered a high attack. (auth.)—NSA. 8895

6.4.2, 3.4.6, 3.4.4

Corrosion of Aluminum in Potassium Chloride Solutions. I. Effect of Concentrations of KCl and Dissolved Oxygen. W. BECK, F. G. KEIHN AND R. G. GOLD. *J. Electrochemical Soc.*, 101, No. 8, 393-399 (1954) August.

The corrosion of aluminum was studied by weight loss measurements in 0.0001N to 1N neutral electrolyte solutions at constant temperature. Oxygen concentration in these solutions was varied over a wide range either by bubbling the gas through the solution or by increasing the partial pressure above the solutions. Weight loss increased with time and increasing oxygen concentration, but decreased with increasing electrolyte concentration. The electrode potential increased in anodic direction with time and increasing electrolyte concentration. Chloride solutions were more aggressive than any other solutions used. Hydrogen peroxide, which might have been a corrosion accelerator in experiments under high oxygen pressure, was found absent in all cases. Results are discussed in the light of the electrochemical theory of corrosion. The relation of oxygen solubility in potassium chloride solutions to corrosion is also discussed. (auth.)—ALL. 8921

6.4.2, 3.5.8

Some Observations on the Tertiary Stage of Creep of High-Purity Aluminum. G. R. WILMS. Defence Standards Laboratories, Report No. 199, Jan., 1954, 13 pp. Available from the Defence Standards Laboratories, Maribyrnong, Victoria, Australia.

Metallographic and X-ray examination indicates that the mechanism of deformation in the secondary and tertiary stages is the same, the changes in structure during the tertiary stage being a consequence and not a cause of the accelerated strain. —BNF. 8836

6.4.2, 3.7.1

Influence of the Distribution of Impurities on the Micrographic Behaviour of Grain Boundaries and Sub-Boundaries After Heat-Treatment in the Case of Two Samples of Refined Aluminium. (In

French). GERARD WYON AND JEAN-MARY MARCHIN. *Compt. rend.*, 238, No. 25, 2420-2422 (1954) June 21.

Experiments were carried out on two sheet specimens of aluminum, one refined (iron 0.004, silicon 0.005, and copper 0.002 percent) and the other super-refined (iron 0.0002, silicon 0.0009, and copper 0.0003 percent). The specimens were homogenized, electropolished, and attacked by aqua regia containing hydrofluoric acid. This attack gave fine corrosion figures, probably localized at the points of emergence of dislocations on the surface. [Cahn, *J. Inst. Metals*, 76, 121 (1949)] if a "dislocation-impurities" relationship obtains. This should explain the modification of the appearance of the boundaries and subboundaries observed after different heat-treatments.—MA. 8819

6.4.2, 3.7.1, 3.5.8

Study of the Corrosion Resistance of Aluminum-Magnesium Alloys. Part I. Relation Between the Stress Corrosion and Microstructure. HIDEO YAMAGUCHI, SHOICHI SAKAMOTO AND MATSUOSHI AOKI. *Light Metals* (Japan), No. 12, 64-69 (1954) August 31.

The relationship between stress corrosion and microstructure of aluminum alloys of 4 to 7 percent magnesium, with and without manganese and chromium, was investigated and it was found that stress corrosion of these alloys is related to the precipitation of the β phase. It was found that high manganese-aluminum alloy reheated at low temperature precipitates the β phase continuously along the grain boundary, which causes stress corrosion cracking in a very short time. Low manganese-aluminum alloy (manganese content below 5 percent) shows no stress corrosion cracking even after reheating at low temperature because the β phase precipitates only as isolated particles. On cold worked material, reheated at low temperature, precipitation of the β phase occurs not only along the grain boundaries but also at slip bands. The tendency toward intercrystalline corrosion of these alloys decreases with slow cooling from the high temperatures. An addition of small amounts of manganese and chromium to aluminum-magnesium alloy decreases the stress corrosion tendency. For practical use the aluminum-4 percent magnesium alloy with a small amount of manganese and chromium is recommended, since it is free from stress corrosion and has good workability and high mechanical strength.—ALL. 8837

6.4.2, 3.5.9, 3.5.8

Influence of the Decomposition of a Supersaturated Solid Solution Brought About by Plastic Deformation on the Mechanical Properties of Aluminum-(1.3%) Copper Alloy (In Russian). V. A. PAVLOV. *Doklady Akad. Nauk S.S.R.*, 95, No. 6, 1201-1203 (1954) April 21.

Determination of variation with temperature (-173 to 407 C) of tensile strength, elongation and work of deformation for 99.97 percent aluminum and aluminum-1.3 percent copper. Graphs obtained for the alloy show "bulges" in the region of 100 C.—BNF. 8859

6.4.2, 6.6.5

The Resistance of Aluminum to Some Alkaline Building Material. T. E. WRIGHT, H. P. GODARD AND I. H. JENKS. *Engineering J. (Canada)*, 37, No. 10, 1250-1256 (1954) October.

The behavior of aluminum in contact with building materials such as concrete,

brick mortars, stucco and plasters, was tested at Aluminum Laboratories Limited, Kingston. Test samples were Alcan alloys 57-S-H, 3S- $\frac{1}{2}$ -H, 3S-F, 50S-A33, and 65S-T in the form of tubing, sheet conduit and extruded bars. The results of the experiments indicated that: 1.) Aluminum alloys are not seriously corroded by contact, over extended periods, with the materials investigated. 2.) Even under continuously wet conditions, aluminum alloys embedded in concrete are only slightly attacked. 3.) Increasing the cement content of concretes increases the amount of attack. 4.) All the aluminum alloys tested perform similarly. 5.) Where aluminum may be in contact with damp concrete or mortar, or with intermittently wet and dry alkaline materials of this type, it is recommended practice to paint the contact surfaces with bituminous paints. 6.) Calcium chloride additions to concrete mixes do not cause an increase in the corrosion rate. However, if stray electric currents are present, corrosion may be greatly increased. In contact with steel, aluminum embedded in concrete containing calcium chloride may be subject to galvanic corrosion. 7.) Where aluminum conduit or structural sections are placed in contact with concrete or mortar surfaces, proper clearance should be arranged between the aluminum members and the structure to avoid a line of contact which may trap and hold water and eventually lead to corrosion.—ALL. 8838

6.4.4, 2.6

Protective Films on Magnesium Observed by Electron Diffraction and Microscopy. SHIGETO YAMAGUCHI. *J. Applied Physics*, 25, No. 11, 1427-1438 (1954) Nov.

Two experimental procedures are described which are useful for the detection of protective films formed on magnesium. 1.) A magnesium ingot with a lustrous surface prepared by etching with hydrochloric solution (35%) was immersed in boiling water for about 10 minutes. The surface was rendered matte by this treatment. The surface was sliced with a knife edge to prepare shavings, which were then immersed in a Grignard reagent (methyl iodide and ethyl ether 1:10 by volume). In this solution the metallic component of the shavings was dissolved away at room temperature. The non-metallic surface films thus freed remained suspended in the solution. The films were collected and washed with ethyl ether and absolute alcohol. The isolated films were examined by means of electron diffraction and microscopy. The existence of oriented crystallites of magnesium hydroxide (hexagonal, cadmium hydroxide type) was shown. In the second method, an etched surface of magnesium was immersed in a sodium fluoride solution (10 percent) for about five minutes at room temperature. Thin films were freed from the matte surface by the same process as for the specimen treated with boiling water. The diffraction pattern verifies the coexistence of magnesium fluoride and hydroxide.—ALL. 8840

6.5 Metals—Multiple or Combined

6.5, 5.11, 3.1

Simple Corrosion Theory as an Aid to Materials Selection. Parts I & II. T. K. ROSS. *Petroleum*, 17, Nos. 4 & 5, 116-118; 154-155, 184 (1954) April, May.

Part I. Chemical immunity, over-potential and film formation considered as phe-

nomena contributing to corrosion resistance. Graphs, diagrams.

Part II, Ross shows how differences in polarity about a metal surface may produce corrosion in seemingly innocuous conditions and tabulates, for four classes of metals, the conditions under which this can occur. 8899

6.6 Non-Metallic Materials

6.6.6, 8.10.2

Lining for Induction Furnaces. H. E. WHITE. *Metal Progress*, 66, No. 3, 99-106 (1954) Sept.

For H. F. furnaces for special steels and heat- and corrosion-resistant alloys, magnesium oxide-zinc oxide mixtures of zircon (zirconium silicate) are used as linings. A table is given of service figures for linings of various alloys. Recommendations on application and ramming, maintenance and repairs. Equilibrium diagrams of the refractories and their relation to induction melting of iron alloys. Physical properties of the refractories. Notes on commercial refractories; aggregate shape and packing.—BNF. 8845

6.6.6, 8.10.2

Operating Practice with the Basic-Lined Cupola. C. GREENLEE. Basic Refractories, Inc. *Foundry*, 83, No. 2, 88-91, 184, 186, 188, 190 (1955) Feb.

Some foundries turned to basic linings in cupolas as a means of obtaining better physical properties in castings. Cost is higher than that of acid lining, but there are various offsetting advantages such as lower sulfur content in iron produced, greater carbon pickup, higher metal tap temperatures, better pouring characteristics, less scrap castings, and substitute of steel scrap for low-phosphorus pig iron without lowering total carbon content. Refractories used in linings, cupola operation, control factors, excessive lining erosion, metal tap temperature, and calcium carbide additions are covered. Diagrams.—INCO. 8793

6.6.8, 5.4.5

Epoxy for Cements and Coatings. R. B. SEYMOUR AND R. H. STEINER. Atlas Mineral Prods. Co. *Chem. Eng.*, 61, No. 4, 244, 246, 248, 250, 252 (1954) April.

Proper role of epoxy cements is yet to be determined, but their properties leave no doubt about their potential usefulness in corrosive applications. Mechanical and physical properties are tabulated and corrosion resistance of these cements to various inorganic and organic chemicals is charted.—INCO. 8884

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1

The Orenda and the Future. B. A. AVERY. Paper before CAI-IAS Intern. Mtg., Montreal, October 14-15, 1954. *Aeronaut. Eng. Rev.*, 14, No. 1, 46-55 (1955) Jan.

Mechanical design of turbojet engine is discussed. The six combustion chambers consist of nickel-alloy liner or flame tube, cast aluminum-alloy front casing, and an aluminized mild steel rear casing. Forward casing is now fabricated of mild steel to match rear casing. Main bodies of inner and outer casing were originally machined from rough stainless steel castings, but now are fabricated of sheet

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metal. Turbine nozzles are precision castings of nickel-cobalt alloy. Quantity of strategic material is less since mounting shrouds are of lower quality stainless. Exhaust cone consists of fabricated stainless steel outer casing and inner cone or bullet. Diagrams.—INCO. 8780

7.1, 3.7.3

How Welding Cures a "Sick" Turbine. L. MCWILLIAMS. Shawinigan Water & Power Co. *Industry & Welding*, 27, No. 12, 49-51, 69 (1954) Dec.; *Modern Machine Shop*, 27, No. 9, 136-139 (1955) Feb.

When turbine blades in hydroelectric plants are eaten away by pitting or cavitation, solution is welding in stainless steel inserts. Step-by-step instructions are given. Semi-automatic inert-arc welding

seems to offer possibilities on the repair of runners. Illustrations.—INCO. 8788

7.3 Pumps, Compressors, Propellers and Impellers

7.3

Application of Helical Gear Pumps. G. H. ZIMMER. Robbins & Myers. *Can. Chem. Processing*, 38, No. 10, 52-60 (1954) Sept.

Operating principles, applications and materials of the helical gear pump. Rotors are often made of Type 316 stainless steel for corrosion resistance. Stators may be made of stainless steel also. Castings are usually made of cast iron, 316 stainless and mild steel. Standard con-

struction materials for shafts and flexible rods are 316 stainless and alloyed carburizing steels. However, when abrasive liquids are used which tend to remove surface oxide films on stainless steels, other materials must be used. Problems of reducing slippage and handling viscous liquids are discussed.—INCO. 8827

7.4 Heat Exchangers

7.4.1, 7.1

Heat Exchangers for Internal Combustion Engines. H. E. UPTON. *Trans. Inst. Marine Engrs.*, 66, No. 5, 101-120 (1954) May.

Details are given of the design, construction, performance, and maintenance of tubular heat exchangers used for oil cooling and other purposes in conjunction with internal combustion engines. Materials of construction and steps to avoid corrosion troubles.—BNF. 8809

7.5.2, 5.9.4

7.5 Containers

Towards Better Containers. *Chem. Eng.*, 61, No. 9, 238, 240 (1954) Sept.

Performance of steel shipping containers is being improved. Recently announced are results of work being done on phosphate treatments at Battelle Memorial Inst. for the Steel Shipping Container Inst., Inc. This work shows that the phosphate pre-treatments must still be considered mainly from their performance on container exteriors and in unlined containers.—INCO. 8908

7.5.5, 5.2.1

How to Save Steel Tanks. H. J. KEELING. *Pipe Line Industry*, 1, No. 3, 68, 70, 73 (1954) Sept.

Cathodic protection for steel tanks is discussed and two general methods for reducing corrosion caused by electrolytic action are cited. One is by insulating the metal surface through application of protective coating to the tank surface; another by applying cathodic protection current to the surface of submerged metal. Most common materials for anodes, including platinum, carbon or graphite, iron, aluminum and magnesium, are discussed briefly.—INCO. 8874

7.6 Unit Process Equipment

7.6.4

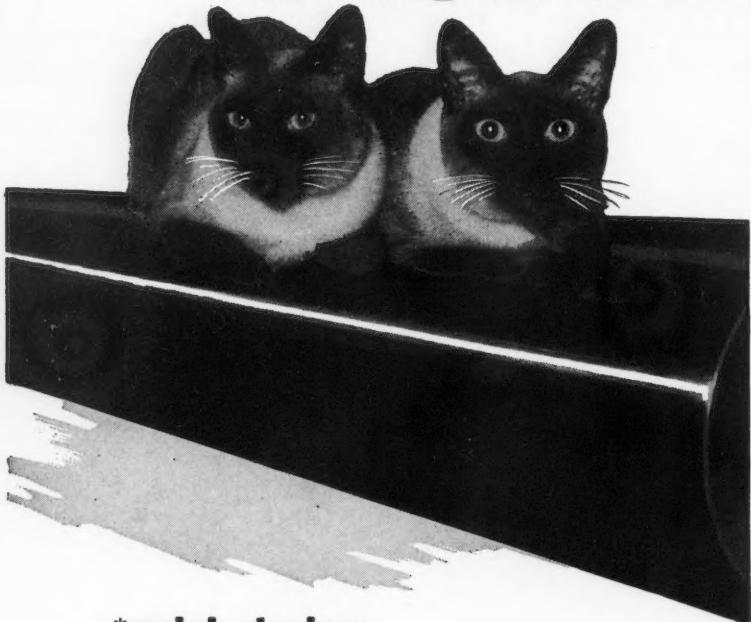
Guard Your H-P Boilers Against These Forms of Corrosion. *Power*, 99, No. 1, 90-93 (1955) Jan.

Corrosion problems found in high-pressure boilers may be caused by improper feedwater treatment, boiler design, or operation. Deterioration due to the action of steam on hot metals, high-temperature creep cracks, intergranular disintegration, corrosion embrittlement, and corrosion fatigue are reviewed. A recorder for determining hydrogen concentration in steam is suggested as an effective means for detecting the rate of attack in a boiler. Illustrations, tables, photomicrograph.—INCO. 8754

7.6.4, 4.6.2, 4.2.3

Eleven Ways to Avoid Boiler Tube Corrosion. H. F. HINST. Babcock & Wilcox Co. *Heating, Piping, Air Conditioning*, 27, No. 1, 166-169 (1955) Jan.

Important mechanisms leading to pitting or water side corrosion, the most

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CORROSION ABSTRACTS

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common type of corrosion trouble in low pressure heating boilers, include presence of dissolved oxygen in the boiler water, velocity, and pH. Methods of removing air and oxygen from boiler water, and the use of inhibitors and alkalizers are suggested as preventive measures. Fire side corrosion, caused by moisture condensing from the atmosphere during periods of shut-down, or from flue gases during operation is accelerated by the use of high-sulfur fuels. Preventive measures include removing accumulations of soot and other products of combustion from the boiler tubes, and oiling the tube surfaces with a good grade of oil after cleaning. Rules for avoiding boiler tube corrosion, covering both in-service and out-of-service factors, are listed. Illustrations.—INCO. 8789

7.7 Electrical—Telephone and Radio

7.7 Metallurgical Research in the Electrical Industry. I. JENKINS. Paper before Midland Metallurgical Societies, *Metal Ind.* (London), **86**, Nos. 1, 2, 3-5; 23-25 (1955) Jan. 7, Jan. 14.

Survey of some of the problems considered by research metallurgists in the electrical industry. Copper, and nickel-chromium-iron, and nickel-iron (50-50) alloys are being used extensively for glass-metal seals. Fabrication of nickel-iron by powder metallurgy ensures close control of expansion. Special manufacturing techniques have been investigated for nickel filamentary cathodes for use in radio valves, to make certain that activating agents such as aluminum, magnesium, or titanium are present in desired form and concentration. Gas content of metal components used in vacuum devices involves study of diffusivity properties of a particular gas in metal concerned so that complete degassing can be accomplished. Glass bead test for indicating gas content of nickel is illustrated. Due to the nickel shortage, nickel-plated iron, nickel-clad iron and nickel-plated copper are being used experimentally for lead-in wires in vacuum devices. Semi-conductors and tungsten filaments are discussed. Illustrations.—INCO. 8781

7.7 Mechanical Design of Electronic Equipment. Special Report. *Electronics*, **27**, No. 10, M 1-M 64 (1954) October.

Papers include: "Importance of Mechanical Design," J. M. Carroll; "Designing the Chassis," J. Lesser; "Making Small Parts," K. B. Clarke and J. W. Courage; "Shielding and Potting," J. S. Burruano, E. F. Bailey and S. Cramer; "Moving Parts," E. Gutman; "Power Devices," H. Sabath, S. R. Sporn and J. Y. Kaplan; "Assembly Techniques," F. T. Schick; "Wiring and Soldering," C. Seelig and C. F. Schultz; "Designing the Cabinet," J. T. Muller.

Report gives the latest in methods, machines and materials. Carbon-steel and stainless are used in the chassis. Protective coating is needed if carbon-steel is used. Aluminum can be plated with chromium, nickel, cadmium, or silver to provide specific decorative or corrosion-resistant finishes. Gaskets and wire are of Monel; shielding materials are of alloys based on elements iron, nickel and cobalt; gears are of stainless; and machine screws are of steel. Mild steel is used for cabinet work, but if weight is a factor, aluminum or magnesium may be used. Tables.—INCO. 8909

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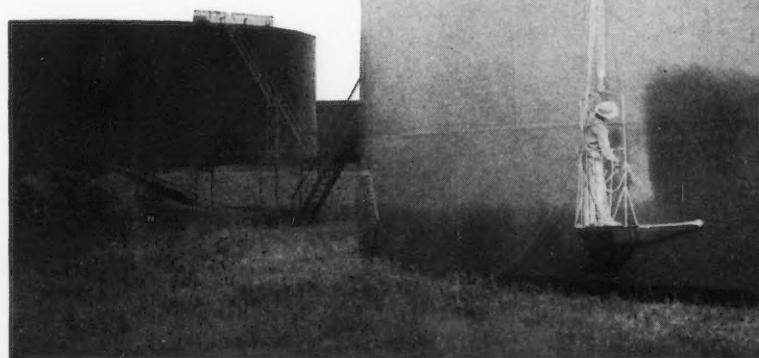
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7.7

Tests and Surveys for Lead Sheathed Cables in the Utilities Industry. Second Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths. Compiled by Task Group T-4B-3 on Tests and Surveys. *Corrosion*, 10, No. 12, 445-463 (1954) December.

Replies to a questionnaire prepared by Task Group T-4B-3 on Tests and Surveys of the National Association of Corrosion Engineers are summarized. Answers are given to questions on practices used in making corrosion surveys on lead sheathed cables underground by 22 companies and electrolysis committees. Companies replying operate both communication and power cables. The replies reveal a wide diversity of practice among the companies. Considerable information on techniques, instrumentation, criteria, materials and pertinent design and operating routine is included. Some recommendations are made for improved materials, methods and future inquiry. 8448

7.7, 1.3

What Causes Underground Cable Corrosion? K. D. FOREST. *Modern Power and Eng.*, 48, No. 11, 63-65, 122-123 (1954) November.

Outline of basic theory of underground corrosion and discussion of practical considerations. Localized galvanic corrosion, occurring when a galvanic couple exists between adjacent portions of the same metallic surface, is generally responsible for the characteristic pitting of lead sheaths on buried cables. Since concentration cells occur when a galvanic couple exists between dissimilar metals, corrosion due to concentration cells is often found where the cable sheath comes into contact with dissimilar metal fittings. External stray currents are a third cause of cable corrosion. Important preventive measures include protective coatings and cathodic protection. Bituminous coatings and petroleum-based greases are most commonly used. The operation of cathodic protection systems is discussed, and methods of detecting corrosion through field testing are considered. Tables, illustrations.—INCO. 8531

7.7, 6.4.2

Compression Terminals for Aluminium Conductors. J. REDSLOE. *Product Eng.*, 25, No. 9, 160-162 (1954) Sept.

Troubles experienced with terminals for aluminum (contact corrosion, creep and thermal expansion); new terminals developed by Aircraft-Marine Products Inc. and consisting of a hollow aluminum alloy cartridge containing an inhibitor (metal powder in petroleum jelly). There are two types: Termalum (with aluminum alloy terminal body) and Copalum (with tinned copper terminal body), for joining aluminum to aluminum and to copper respectively.—BNF. 8725

7.8 Wires and Cables (Non-Electrical)

7.8, 3.5.8

Prestressing Wires—Stress-Relaxation and Stress-Corrosion Up to Date. G. T. SPARE. U. S. Steel Corp. Paper before Wire Assoc., Ann. Conv., Nov. 9, 1954. *Wire and Wire Products*, 29, No. 12, 1421-1424, 1492-1493 (1954) Dec.

High strength steel wires used in prestressing need protection from corrosion. Under stress, irregular corrosion creating notch effects, hydrogen embrittlement, or stress-corrosion cracking can cause sud-

den wire failures. Free-loop tests described demonstrated convincingly the high susceptibility of heat-treated wires to various types of stress corrosion. Static load relaxation for these high strength wires has been fairly well defined by recent wire industry work. Preliminary work on resistance to dynamic loads in high stress range suggests adequate safety. Graphs and photomicrographs.—INCO. 8713

7.8, 4.4.7

Surface Temperature: Lubrication Relations during Drawing of Copper Wire. J. S. HOGGART. *Wire Production*, 3, No. 2, 4-5, 7, 9 (1954) January.

Calculation of temperature rise and experimental determination; die wear; determination of coefficient of friction using various lubricants. Measurements of surface temperature proved useful for comparison of lubricants. Most satisfactory lubrication was obtained with soap emulsions, high speeds and light drafting.—BNF. 8477

7.8, 6.3.9, 5.3.4

Oxidation Resistance of Diffusion Coatings on Sintered and Swaged Molybdenum Wire. C. J. LEADBEATER AND D. T. RICHARDS. *Metal Treatment*, 21; Nos. 106, 107; 309-315, 387-396 (1954) July, Aug.

Volatile oxidation of molybdenum oxide at elevated temperatures may be suppressed or prevented by coating the molybdenum with different metals more resistant to oxidation. Study of this was made and description of work with conclusions from collected data are given. Composite coatings on molybdenum included metal coatings of beryllium, titanium, zirconium, silicon, vanadium, chromium, nickel and boron, which subsequently were carbured, boronized, aluminized or chromized. Reactions occurring by continual heating at different temperatures are discussed. Factors such as composition, smoothness and thickness of coating and cyclic instead of continuous heating are critical in influencing life of coated molybdenum and these are examined. Photomicrographs, graphs, tables and 4 references.—INCO. 8413

7.10 Other

7.10, 1.3

Gaskets. Part I. Seals. S. EILONKA. *Power*, 98, No. 3, 105-124 (1954) March.

Review of the latest information on sealing materials and methods—time proven methods as well as new ones. Materials discussed include asbestos, rubber, plastics, lead, tin, aluminum, copper, brass, silver, ingot iron, low-carbon steel, chromium steel types 502 and 410, and stainless steel types 347 and 316. Monel is excellent at normal or high temperatures because it resists most alkalis and other corrosive agents. Nickel won't stand up in all-around service as well as Monel, but it's good to 950 F with chlorine. Platinum, because of its high cost, is used only when no other gasket material will resist corrosive attack. Stainless steel type 304 is most used for gasketing against corrosion. Illustrations.—INCO. 8407

7.10, 6.4.2

Light-Metal Rivets and Screws. (In Italian). L. GAZZANIGA. *Alluminio*, 22, No. 1, 52-57 (1954) January.

A short survey is given on fabrication, machining, anodic protection, thermal treatment, corrosion resistance and application of aluminum-rivets and screws.

Technical data are provided on materials suitable for rivet and screw fabrication, i.e. Recidal 45, Avional 24, Anticorodal 11, Peraluman 50 and Ergal 65.—ALL. 8524

7.10, 1.6

Storage Batteries. G. W. VINAL. Book 4th edition, 1955, 446 pp. John Wiley and Sons, Inc.

Recent technological advances in battery design and construction including improved lead alloys for corrosion-resistance, production of nickel-cadmium batteries in this country, increased use of plastic containers and new types of silver oxide cells are added in new edition.—INCO. 8756

7.10, 6.3.8

Here's How Battery Research Improved Lead Casting. H. E. ZAHN. *Precision Metal Molding*, 12, No. 9, 68-69, 72, 103-104 (1954) Sept.; *Iron Age*, 174, No. 12, 174-175 (1954) Sept. 16.

Use of new grid designs eliminated microporosity at junctions and solidification cracking, leading to more uniform corrosion of the metal and hence a reduction in metal required but more active material per plate. Also methods for withdrawal of dross and prevention of gas entrapment.—BNF. 8830

7.10, 6.4.2

Aluminum Fixing Accessories for Building Purposes. British Standard 2465: 1954, 12 pp. British Standards Institution, 2 Park Street, London, W. 1.

Materials and dimensions for hook bolts and nuts, drive screws, washers for aluminum roofing sheet and roofing bolts and nuts, suitable for use when the structure to which they are attached is also of aluminum or aluminum alloy or where suitable protection against galvanic corrosion can be provided.—BNF. 8913

7.10, 6.6.7

Rubber Hose Gets Better. J. A. MULHER. *Chem. Eng.*, 62, No. 1, 224, 226, 228, 230 (1955) Jan.

Advances in rubber chemistry have enlarged the usefulness of hose. Rubber in the tubes can now be compounded to resist attack by oil, butane, propane, acetylene, insecticides, paints, lacquers, mild acids and a host of other chemicals. Hoses carry dry and wet solids as well as gases and liquids. Abrasion resistance is built into the tubes. Hoses for carrying steam, hot water or other hot liquids also have heat-resistance incorporated in the rubber of the tube.—INCO. 8762

8. INDUSTRIES

8.1 Group 1

8.1.2, 6.3.6

Application of Copper in Building. (In French and German). F. SCHINACHER. *Pro-Metal*, 6, No. 37, 296-303 (1954).

Guttering and down pipes, complete roofs, strip edging for asphalt or bituminous-paper roofs are most advantageously made in copper. The economic factors favoring the use of copper are more prominent at present than they were 30 or 50 years ago. Many old buildings have exterior fittings of galvanized iron which need to be replaced after reaching the end of their useful service life and their replacement with copper is recommended, provided precautions are taken against galvanic corrosion at points where copper is in contact with any remaining pieces of the old materials.—MA. 8643

8.1.2, 8.1.4, National Requirements. 186 pp. American Engineers, New York 18, N.Y.

This is after two practices plumbing architects, engineers, building code embeds. Plumbing which begins towards the end of November.

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8.2 Gr

8.2.2, 7.6.4. Corrosion Steam Pipe Permitt. (1954) O.

Solutions feedwater wet stage surfaces basis of air aerating deaerating given. Graph, m

8.3 Gr

8.3.1, 4.4. Corrosion C. F. Sc Téc. Results. Exp. Struc. mat. Monel a butyral sprays a treatment cides, he

8.3.1, 8.9. Corrosion materials by Laborat. pounds. BAUER. C. Feb.

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8.1.2, 8.1.4, 1.6

National Plumbing Code. Minimum Requirements for Plumbing, Book, 1955, 186 pp. American Society of Mechanical Engineers, 29 West 39th Street, New York 18, New York.

This is the uniform code developed after twenty years to modernize existing practices and coordinate the work of plumbing equipment manufacturers, architects, contractors, municipal law makers, building officials and others. The new code embodies a report by the National Plumbing Code Coordinating Committee which began work in 1949. The Standards Council of the American Standards Association said there was general agreement at a New York meeting of ASA in November 1954 in favor of the code.

A careful search of the code fails to reveal attention to corrosion hazards except a provision for wrapping pipe to prevent external corrosion when it passes through or under cinder or concrete or other corrosive material. Ferrous pipe used underground shall be coal tar enamel coated and threaded joints coated and wrapped after installation, the code states in another place. Galvanic corrosion apparently is not considered. 8881

8.2 Group 2

8.2.2, 7.6.4, 7.4.2

Corrosion Control in Industrial and Steam Power Plants. R. M. LEMEN. The Permutit Co. *Combustion*, 26, No. 4, 38-44 (1954) Oct.

Survey of corrosion problems, possible solutions in boilers and economizer, boiler feedwater circuits, condensate return lines, wet stages of turbines, and heat exchange surfaces of cooling water systems. Analysis of applicability and limitations of de-aerating heaters, open heaters, vacuum deaerators as preventative equipment is given. Diagrams, photographs, tables, graph, micrograph. 3 references.—INCO, 8918

8.3 Group 3

8.3.1, 4.4.7

Corrosion by Agricultural Chemicals. C. F. SCHRIEBER AND F. E. WEICK. *Corrosion Technology*, 1, No. 8, 295 (1954) Oct.

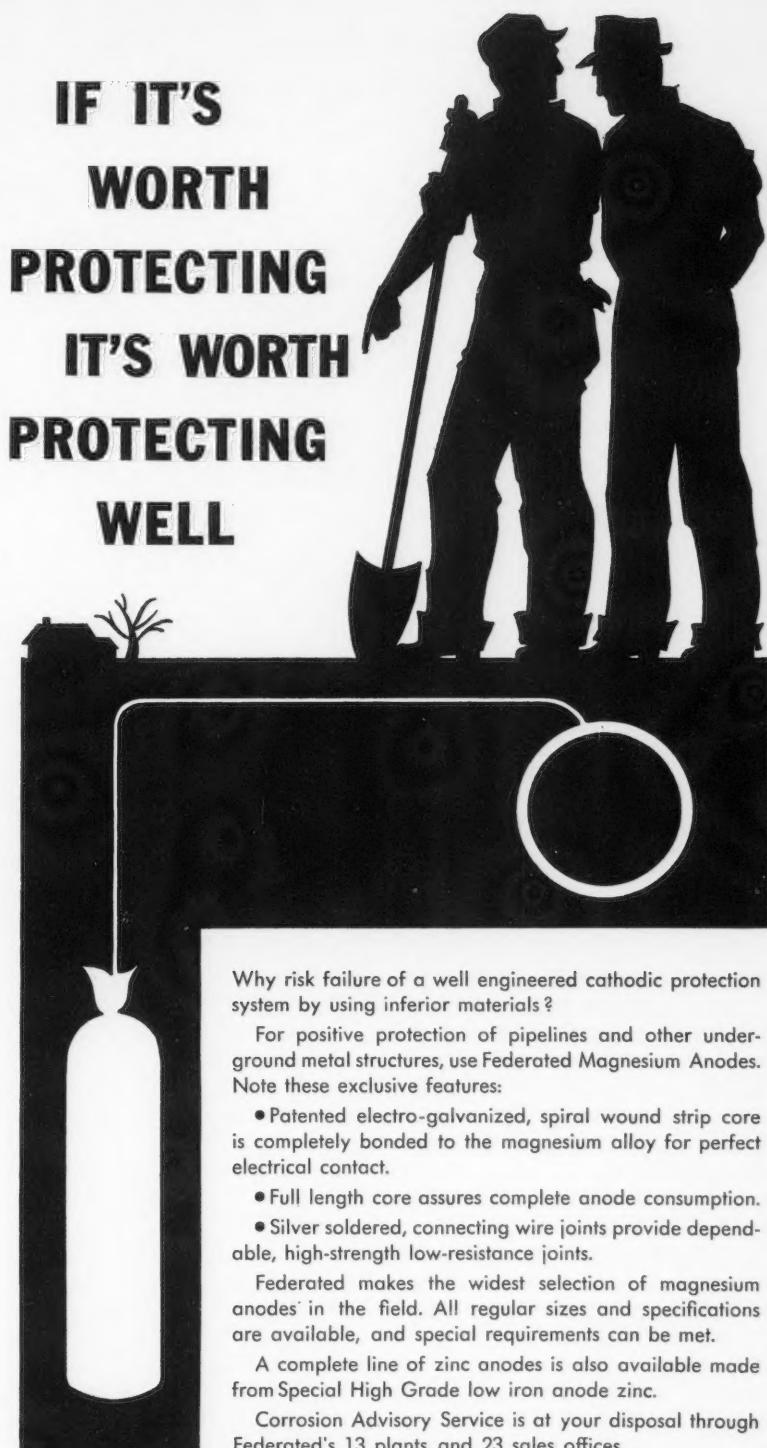
Results of investigation at Texas Eng. Exp. Station showed that only 2 structural materials, Type 302 stainless and Monel and 1 finish, furan coating with butyral primer, were resistant to the sprays and dusts commonly used in crop treatment by aircraft. Agricultural chemicals used included insecticides, fungicides, herbicides and fertilizers.—INCO, 8646

8.3.1, 8.9.1

Corrosion of Aircraft Structural Materials by Agricultural Chemicals, Part I. Laboratory Tests with Fertilizer Compounds. T. MARSHALL AND L. G. NEUBAUER. *Corrosion*, 11, No. 2, 44-52 (1955) Feb.

Corrosion tests are described, related to the aerial distribution of agricultural chemicals in New Zealand. They indicate that the following compounds are not significantly corrosive towards aircraft structural materials under the conditions obtaining in operating aircraft: agricultural lime, meat-and-bone meal, basic slag, burnt lime.

The following compounds are sufficiently corrosive to make protective coating systems a useful precaution: super compounds, serpentine superphosphate, superphosphate, cobaltized super com-



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The following compounds are significantly corrosive towards one or more important aircraft structural materials: nitrolime, ammonium sulfate, muriate of potash, copper sulfate.

The effects of the above compounds on a few protective coating systems are also given and further tests now in progress are outlined briefly.

caused by many chemicals which they must withstand.—INCO. 9095

8.3.1, 5.4.5

Problems and Materials of Sprayer Construction. W. H. ZEHNER, F. E. Myers & Bros. Co. Paper before Am. Chem. Soc., Div. of Agric. & Food Chem., 125th Nat. Mtg., Kansas City, Mo., March 26, 1954. *J. Agric. and Food Chem.*, 2, No. 22, 1104-1106 (1954) October 27.

Corrosion, chemical accumulation, and abrasion are the chief problems in sprayer construction.

Corrosion of steel sprayer tanks, caused by the spray mixture and accelerated by the type water used or by atmospheric conditions, is an especially acute problem. Due to the high material and fabricating costs of corrosion-resistant steel, a good corrosion and chemical resistant coating for steel tanks is a solution to the problem. Protective coatings must possess good adhesion to the base metal, solvent resistance, flexibility and elasticity, abrasion resistance, and economy. Bituminous, chlorinated rubber, neoprene, vinyl, air-drying and heat curing epoxy and phenolic resin and porcelain enamel coatings are evaluated. Cost and design limitations of fiberglass-reinforced polyester resin tanks have handicapped them for commercial use.—INCO. 9091

Corrosion of Aircraft Structural Materials by Agricultural Chemicals. 2. Effect of Insecticides, Terbicides, Fungicides and Fertilizers. CHARLES F. SCHREIBER. *Corrosion*, 11, No. 3, 33-44 (1955) March.

The corrosive and surface destruction effects of the generally used agricultural chemicals were tested on the structural materials and finishes used in agricultural aircraft and dispersing equipment. A total of 512 specimens of structural materials and finishes were tested partially submerged and 297 were tested under atmospheric conditions.

A thorough study was made of the agricultural chemicals that are now commonly applied by aircraft. New compounds that have a promising outlook in the crop dusting program also were included. The structural materials tested included the most frequently used metals, basic finishes, plastics and doped fabrics. Because there are more than 3000 protective coatings on the market, only the fundamental finishes could be included in this investigation.

As an overall summary of results it was found that only two materials tested, Type 302 stainless steel and polyester plastic reinforced with fiberglass, offered complete protection from all of the solutions investigated. Monel metal resisted corrosion reasonably well, but brass, aluminum alloy and chrome-molybdenum steel were all destroyed by certain of the agricultural chemicals.

A furan protective coating with a butyral primer demonstrated the best overall finish characteristics, although none of the applied finishes that were tested withstood all of the agricultural chemicals without damage.

For Part I see: Laboratory Tests with Fertilizer Compounds. T. MARSHALL AND L. G. NEUBAUER. *Corrosion*, 11, No. 2, 44-52 (1955) February. 8705

8.3.1

Application of Chemicals with Air Sprayers. J. P. CARR AND J. M. PATTERSON. Food Machin. & Chem. Corp. Paper before ACS, Div. of Agric. & Food Chem., 125th Nat. Mtg., Kansas City, March 26, 1954. *J. Agric. and Food Chem.*, 2, No. 22, 1102-1104 (1954) Oct. 27.

Discusses objectives, advantages, and difficulties of application of chemicals with air sprayers. Corrosive effects of the chemicals cause the greatest difficulties and materials satisfactory for tanks, pump parts, pipes, hoses, and nozzles must be corrosion-resistant as well as durable. Steel tanks, commonly used because of cost and strength qualities, are given an integral coating of a resistant material. Zinc bonded to the steel by the costly and difficult Metallizing process, is the most satisfactory coating yet found. Pump and nozzle parts made of the finest abrasion resistant materials available are frequently the first parts requiring replacement because of the severe abrasion

8.3.4, 6.4.2, 5.9.4, 8.8.2

Advantages of Anodic Oxidation of Aluminum Containers for Aqueous Solutions of Alcohol and Brandies. (In Italian). V. TAMBURRINI. *Alluminio*, 23, No. 2, 151-152 (1954) March.

Results of corrosion tests show that anodizing affords adequate protection for containers in the wine industry (including distillation).—BNF. 8906

8.3.5

Metallic Corrosion in the Baking Industry. F. J. H. OTTAWAY. *Cookery Technology*, 1, No. 9, 322-327 (1954) Nov.

Various points at which corrosion occurs in the bakehouse are discussed and probable factors involved are mentioned. Corrosion is most serious in ovens and oven fittings at points where steam containing acid gases can condense, and in bread provers in which there is a high temperature and humidity. Mixer bowls are made of steel and are sometimes tinned; under no circumstances should these bowls be galvanized. Dough divider is a good example of the influence of both corrosion and wear. It was found that by changing from edible to mineral lubricating oil, there is a reduction in corrosion. Tables used for picking over dried fruit after it has been washed are now made of stainless steel. Illustrations.—INCO. 8905

8.3.5

Chemical Engineering Methods in the Food Industry—Handling of Liquids in the Factory. R. FALCONER. Paper before Soc. Chem. Ind., Chem. Eng. Group & Food Group, London, March 18-19, 1954. *Chemistry & Industry*, No. 35, 1058-1063 (1954) August 28.

Handling of liquids is considered in stages of storage, transfer, mixing, filtration, measuring and filling into containers. Since it is only the surface in contact with the product that is important in considering corrosion, it is economic to use thin mild steel sheets clad with nickel or nickel-chromium instead of using stainless steel. A table of materials commonly used for handling various liquids includes Monel, mild steel, stainless, nickel alloys, austenitic cast iron, and high silicon steel. Pipes and fittings, valves, pumps, filters and storage tanks are discussed. 27 references.—INCO. 8889

8.4 Group 4

8.4.3, 4.6.2

Cities Service Recovers 740 G.p.m. Condensate as Result of Modifications to Flow System. F. L. RESEN. *Oil Ga. J.*, 53, No. 29, 96-98 (1954) Nov. 22.

Four vertical pressure-type filters at Lake Charles, La., butadiene plant enable recovery of makeup water from oily condensate flow system. Filtered condensate contains 0.5-1.75 ppm iron which reacts with phosphate in corrosion inhibitor and precipitates, thereby necessitating increased use of corrosion inhibitor. To offset these conditions, first two filters break the oil-water emulsion, passing through the iron, condensate stream is aerated to oxidize the iron, and remaining filters remove iron oxide. Flow sheet.—INCO. 9068

8.4.3, 5.7.7

Phillips Tests Air-Mud Drilling. R. A. BOBO, G. S. ORMSBY AND R. S. HOCH. *Oil Gas J.*, 53, Nos. 38, 40; 82-87, 104-108 (1955) Jan. 24, Feb. 7.

Corrosion of drill pipe, problem on first test, responded to chemical control. Possibility of using saturated lime water to maintain pH for corrosion control as well as low viscosity was investigated. Saturated lime proved to be effective, easy to control, and relatively cheap to maintain. Tables, graphs, and 11 references.—INCO. 8774

8.4.3

Corrosion in Sweetening Units. *Petroleum Refiner*, 33, No. 4, 135-137 (1954) April.

Pitting of bed vessels, storage tanks and process piping and loading lines in Perco treaters is discussed. Use of chemical inhibition and surface coating in combating corrosion in these places is covered. Table.—INCO. 8682

8.4.3, 5.3.8

Sulfide Corrosion Cracking of Oil Production Equipment. A Report of Technical Unit Committee 1-G on Sulfide Stress Corrosion Cracking. *Corrosion*, 10, No. 11, 413-419 (1954) Nov.

Field experience with sulfide corrosion cracking of production equipment, particularly tubing and casing, in sour gas-condensate and high pressure sour oil wells is summarized along with data from recent field tests. Preventive measures are described including selection of

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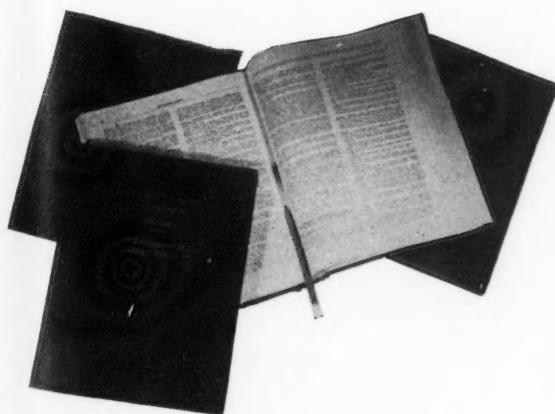
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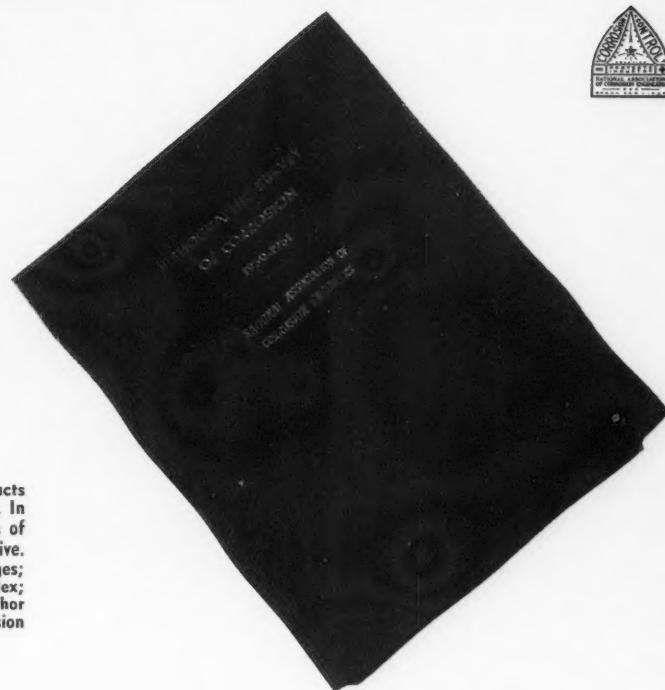
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materials with minimum susceptibility to cracking and use of inhibitors. Laboratory and field test methods are reviewed.

General status of the sulfide corrosion cracking problem as it exists is described and future problems involved in very deep sour wells are considered. 8445

8.4.3, 4.6.2

Acid, Water and Sulfide Corrosion Combined. W. L. NELSON. *Oil Gas J.*, **53**, No. 1, 181 (1954) May 10.

In the distillation of brine-bearing crude oils, a triple threat corrosive condition usually arises, namely the combined attack of dilute hydrochloric acid, hydrogen sulfide and the various attacks of cooling water. Types of alloys (includes red brass, Admiralty metal, Muntz metal, copper-silicon-manganese, aluminum brass, aluminum bronze, nickel silver, copper-nickel, Monel, Inconel, Hastelloy B and C, steel, and 18-8) used to combat this combination of corrosive actions are tabulated and discussed. Aluminum, nickel, Inconel and copper-base alloys are also used. Where the temperature is high (above about 450°F) as in certain vacuum plants, stainless steel (13% chromium or 18-8) is required.—INCO. 8667

8.4.3, 5.11, 4.6.11

Gas Gathered From Offshore Locations Will Power and Feed Large Chemical Plants. F. L. RESEN. *Oil Gas J.*, **53**, No. 29, 100-102, 104-107 (1954) Nov. 22.

Description of Texaco's remote compressor stations, 88 miles of trunk gathering lines and the Paradis gasoline plant which provide for utilization of oil-well gas from almost inaccessible locations. Compressor stations of submerged-barge-mounted type were designed to provide minimum projected area to wave-water action under severe conditions, thus minimizing water-line corrosion. Work done by U. S. Army Engineer Corps was guide to maximum wave crests and hurricane history of the area. Columns supporting deck were covered with conventional pipe coating to prevent corrosion and sheathed in cement to minimize effects of abrasion, marine life and wave action. Illustrations.—INCO. 8735

8.4.5

How Radiation Affects Structural Materials. C. R. SUTTON AND D. O. LEESER. *Iron Age*, **174**; Nos. 8 & 9; 128-131, 97-100 (1954) August 19, August 26.

A short survey. Effect on mechanical and physical properties (tensile strength, elongation, density, electrical resistivity) of steels, nickel-base and cobalt-base alloys and zirconium. Methods of test. 8697

8.4.5

How Nuclear Radiation Affects Engineering Materials. D. O. LEESER. Argonne Nat. Lab. *Materials & Methods*, **40**, No. 2, 109-120 (1954) August.

Survey of behavior of various structural engineering materials, such as stainless steels, C-steels, Ni and Ni-base alloys, Monel, K Monel, Inconel, Inconel X, and Hastelloy C, when subjected to nuclear irradiation. Manual covers effect of radiation on the hardness, tensile strength, impact, magnetic susceptibility and electrical resistivity, effect of radiation on some nonmetallics and neutron absorption. 15 references and tables.—INCO. 8420

8.4.5

Corrosion and Impurities in the Heavy-Water System of the Dutch-Norwegian

Reactor. T. J. BARENDEGRT AND K. H. BRAKSTAD. Joint Establishment for Nuclear Energy Research, Kjeller, Norway. *Nuclear Engineering*, Part I, Chem. Eng. Progr. Symposium Ser. No. 11, 183-187 (1954).

The design and performance of the JEEP reactor is briefly discussed. Results of corrosion and impurity checks on aluminum canning are given. Laboratory experiments with distilled 210° water in an autoclave for 100 hrs. indicated that type 2S aluminum was the most resistant to corrosion. The corrosion effects in the reactor were mainly caused by D₂O contamination. Inspection of the valves, pumps, and heat exchanger of the D₂O system showed corrosion attacks on the stainless steel, which resulted in rust particles in the system. An increase in conductivity and decrease in the pH of the system indicated the presence of impurities. Results of an analysis of the D₂O system for impurities and causes of radioactivity after operation are given.—NSA. 8923

8.4.5, 4.7

Fuel Processing Loops: How They Are Being Developed. C. RASEMAN AND J. WEISMAN. *Nucleonics*, **12**, No. 7, 20-25 (1954) July.

To prove the feasibility of salt-extraction for removing rare-earth fission products from liquid-metal fuel, an in-pile experiment with an LMFR processing loop is in progress. Tests run to develop components and processing techniques of the in-pile loop are described. Tests led to the choice of type 347 stainless steel for use in the in-pile experimental loop. The austenitic stainless steels are attacked transgranularly by the uranium-bismuth solution and some nickel is leached from the steel under isothermal conditions. On basis of weight of nickel dissolved and on assumption that all of it has leached from corrosion areas, penetration of type 347 is about 2 mils after 3,400 hr. After uranium-bismuth was pumped through system for 2,400 hr. at 1 ft/sec. and 450°C, the all-welded type 304 loop with type 347 pump cell showed no plugging, isothermal operation avoiding mass transfer. Type 347 pump cell showed no carbide precipitation. Type-G3 GE a-c electromagnetic pump failed at 4,440 hr. due to poor electrical contact between one pump-cell lug and pump busbar, causing severe oxidation; trouble was corrected by using copper leads to bypass current through outer lug surfaces and contact faces. Illustration, schematic diagrams, 6 references.—INCO. 8865

8.4.5, 5.3.4

Electrocladding of Reactor Materials.

J. G. BEACH AND C. L. FAUST. Battelle Mem. Inst. *Nuclear Engineering* (Pt. I, Chem. Eng. Progress Symp. Ser.), **50**, No. 11, 31-38 (1954); *Products Finishing*, **19**, No. 4, 48, 50, 52, 56, 58, 60, 62 (1955) Jan.

Poor corrosion resistance, tendency toward galling, and difficulty in joining to other metals are characteristic of materials used in reactors which most frequently need electroplating. Due to high temperatures encountered in use, rate of alloying and properties of alloys formed are important factors in coating choice. Low neutron absorption is another important consideration. Practical limit on nickel coatings is about 5 mils and, frequently, less than 1 mil is all that can be tolerated. Surface preparation and activation are discussed and specific procedures for activation of surface of aluminum,

magnesium, beryllium and zirconium base metals are given. Choice of plating baths is considered and four nickel baths, with appropriate operating conditions, are tabulated. Diffusion-alloying of plated zirconium and beryllium is described and effect of time and temperature of heat treating on bond strength of nickel-plated zirconium is tabulated. Photomicrographs of nickel-plate on beryllium are shown.—INCO. 8777

8.4.5, 6.5, 2.3.1

Materials Development for the Submarine Thermal Reactor. W. A. JOHNSON. *Westinghouse Engr.*, **14**, No. 6, 208-212 (1954) Nov.

Discusses testing and selection of materials for the Mark I plant (prototype of submarine reactor). Zirconium was selected for structural applications within the reactor itself. Effect of impurities in zirconium on corrosion resistance, physical and mechanical properties, melting of zirconium and other fabrication problems are presented. Corrosion tests showed that sponge zirconium was entirely unsatisfactory, crystal-bar zirconium corrosion resistance is damaged by carbon, nitrogen, aluminum and titanium impurities, zirconium must be etched to remove residual stresses remaining on surface to lessen corrosion, and de-aerating procedures were necessary to remove harmful nitrogen. Discussion of materials for non-nuclear applications includes type 347 stainless steel, cupronickel, Stellite, Inconel and chromium-plated stainless. Tantalum contained in type 347 stabilized with niobium becomes highly radioactive so lower tantalum and higher niobium contents are specified than in usual commercial steels; however, unstabilized austenitic stainless steel is satisfactory for majority of reactor applications. Three systems used to study corrosion in reactor systems are tests with autoclaves, dynamic tests out-of-pile to measure corrosion-crust and water composition effects, and radiation-corrosion test of production fuel assembly.—INCO. 8863

8.5 Group 5

8.5.3, 6.4.2

Structural Aluminum Resists Corrosion in the Pulp and Paper Industry. J. R. AKERS AND J. GAMMON. Reynolds Metals Co. *Paper Ind.*, **36**, No. 8, 803 (1954) Nov.

Aluminum and aluminum alloys are being used by the pulp and paper industry for ventilating ducts, screen covers, walkways, railings, ladders, suction boxes, conduit, certain pipe lines and many other applications because of the ability of aluminum to resist corrosive fumes due to its naturally-formed coating of aluminum oxide and its light weight and low maintenance costs. Periodical painting is not necessary for aluminum because almost any corrosive attack tends, at the same time, to coat the metal with more aluminum oxide and thus lessen the rate of each successive attack and with increasing time of exposure. Results of a 14-year test of a number of aluminum alloys exposed to a highly contaminated industrial atmosphere show that if the depth of corrosion were plotted against time, the curve would rise rapidly at first, then flatten out and become almost parallel with the time axis.—INCO. 8569

8.5.3, 7.2

Stainless Steel Valves and Fittings in the Pulp and Paper Industry. P. C. SHAF-

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8.8 Group

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per Cooper Alloy Corp. Paper before Can. Pulp & Paper Assoc., Tech. Sec., Victoria, B. C., June 15-18, 1954. *Pulp Paper Can.*, 55, No. 10, 138-146 (1954) Sept.

Discusses alloys and applications, valve selection, design factors, installation and maintenance of valves and fittings. Tables list chemical compositions, physical and mechanical properties for 14 cast alloy types used to combat corrosion. Alloy types listed are various chromium-nickel stainless steels, Hastelloys C, Monel, Monel "S" and nickel. Corrosive chemicals in the industry and alloys recommended to resist them are tabulated.— INCO. 8637

8.8 Group 8

8.8.1, 4.2.2
Corrosion Problems in Phosphoric Acid Manufacture. J. J. PORTER AND G. C. LOWRISON. Paper before Inter. Superphosphate Manufacturers' Assoc., 1954 Tech. Mtgs., Cambridge. *Ind. Chemist*, 30, 369-373 (1954) August.

With exception of high molybdenum (15-20%) nickel-chromium alloys, authors have not found any material which will withstand all conditions, although manufacturers claim that alloys of the % composition—carbon 0.07%, chromium 19.22%, nickel 28-30%, silicon 1.5%, molybdenum 2-2.5%, and copper 3-3.5%—and certain aluminum bronzes, are also highly resistant. AISI 317 (nickel 11-14%, chromium 18%, molybdenum 3-4%) is far superior to AISI 316 (nickel 10-14%, chromium 18%, molybdenum 1.75-2.5%) in resistance to wet-process phosphoric acid, but has been in short supply in England, 316 being available; 316 has life half that of 317. Carbon content is extremely important. Stabilization with titanium or niobium is no remedy for high-carbon content.—INCO. 8691

8.8.1, 6.5
Use of Metallic Materials and Corrosion in the Chemical Industry. (In Italian). G. PASTONESI. *Metallurgia italiana*, 46, special supplement to No. 5, 37-41; disc., 41 (1954) May.

Applications of nickel-base alloys, weld deposited alloys and other non-ferrous materials. Corrosion phenomena in the chemical industry.—BTR. 8598

8.8.3, 5.8.2
1) **Effect of Surface-Active Substances on the Corrosion of Cathode Zinc. 2) Reasons for the Inhibition of the Corrosion of Cathodic Zinc in the Presence of Surface-Active Substances.** (In Russian). V. S. KOLEVATOVA AND A. I. LEVIN. 1) *Applied Chem. USSR* (Zhur. Priklad. Khim.), 27, No. 4, 456-460 (1954) April; (2) *ibid*, 27, No. 5, 506-513 (1954) May.

1) Measurement of the rate of hydrogen evolution was used to determine the effectiveness of glue, β -naphthol and soaproot in combating the increased corrosion of zinc cathodes in sulfuric acid due to the presence of nickel, antimony, copper or cobalt in the bath. These surface-active substances had a similar beneficial effect on the current efficiency and quality of the zinc deposit from acid baths (aluminum cathode, lead anodes). 2) As the concentration of glue, β -naphthol or soaproot in the bath (zinc sulfate/sulfuric acid) increased, the overvoltage of hydrogen on nickel, cobalt, copper and antimony electrodes passed through a maximum and the anodic potential of zinc became less negative.—BNF. 8419

The advertisement features a large anchor graphic with the text "...Complete Facilities for Applying ANCHORCRETE" overlaid. To the left, a black arrow points towards the text "Available at PLS Harvey, La." Below the anchor, there are two images: one showing a close-up of a pipe's end with a textured coating, and another showing a long section of a corrugated pipe.

View of PLS-Anchorcreted pipe showing reinforcing wire mesh exposed for field-applied concrete joint.

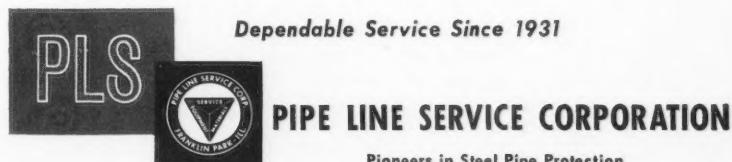
To anchor lines in places where conditions of buoyancy exist, PLS-Harvey offers complete facilities for applying dependable Anchorcrete reinforced concrete coating to PLS-coated-and-wrapped pipe.

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Ample storage facilities make it possible for you to take delivery of your Anchorcreted pipe when it is needed. What's more, PLS-Harvey has more than 600 feet of dock space equipped with traveling crane to provide speedy loading by experienced PLS hands directly onto your barge. This eliminates unnecessary handling and assures delivery of protected pipe in perfect condition.

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8.8.1, 4.3.2

Diammonium Phosphate Fertilizer from Wet-Process Phosphoric Acid. E. C. HOUSTON, L. D. YATES AND R. L. HAUNSCHEID. Paper before Am. Chem. Soc., 126th Mtg., Symp. on Fertilizer Technol., New York, Sept., 1954. *J. Agric. and Food Chem.*, 3, No. 1, 43-48 (1955) Jan.

Equipment in the pilot plant was made from stainless steel, with the exception of the dryer, which was made of aluminum. Corrosion rates of stainless steel, steel, Duriron, and Everdur 1010, in diammonium phosphoric mother liquor are tabulated. Part of the plant handling phosphoric acid—namely, acid storage tanks and ammoniator—should be made from AISI Type 316 or 317 stainless steel. Rubber-lined steel is an alternative for construction of storage tanks. Graphs, tables and 8 references.—INCO. 8869

8.8.1, 5.1, 1.6

Corrosion Problems and Prevention in the Chemical and Petro-Chemical Industries in the U.S.A. Brochure, August, 1954, 129 pp. Published by Organization for European Economic Co-operation, 2 rue Andre-Pascal, Paris 16e.

This is a report of O.E.E.C. Technical Assistance Mission No. 130, a group of 21 representatives from 10 countries who visited the U.S.A. in 1953 to study problems of maintenance in the chemical industry, with special reference to corrosion. The conclusions drawn are discussed in the light of theory and method; protective techniques; and anti-corrosive and heat-resisting materials. This highly interesting report deserves study.—BNF. 9070

8.8.5, 6.4.2

Heat Transfer to Aluminium. K.

MARSH. Typscript, Industrial Furnace Manufacturers Assn., Spring, 1953, 46 pp. (In Progress); *Ind Heating*; 21; Nos. 4, 5, 6; 658-660, 662, 664, 666, 804; 898-910 (even pages); 1120-1132 (even pages), (1954) April, May, June.

Detailed information for use in the design of furnaces for heating aluminum. Author is in charge of Alcoa's furnace division and gives performance data obtained by the company. The version published in *Industrial Heating* contains some additional information.—BNF. 9076

8.8.5, 6.6.6, 1.7.1

Ceramic Tools: They Cut Alloy Steel at 1200 Sfpm. *Am. Machinist*, 99, No. 5, 153 (1955) Feb.

Fourteen ceramic cutting tools have been under investigation in Rodman Process Lab. at Watertown Arsenal. S-1052, a high-purity aluminum oxide tool, has been used to cut 4140 steel at 1200 sfpm, with feed of 0.008 ipr, and 0.125-in. depth of cut. S-1052 has excellent erosion resistance and can be held in tool holders that are closer to normal commercial standards. A comparative test indicated that life of S-1052, between grinds, was between that of C-6 and C-7 carbides. Development program will continue, with investigation of other ceramics, tool design, life of ceramic tools, and possibilities for operations other than uninterrupted lathe turning, the only one tried to date. Illustration.—INCO. 8787

8.8.1

French Synthetic Detergents From Petroleum. G. C. INSKEEP AND A. MUSARD. *Ind. & Eng. Chem.*, 47, No. 1, 2-10 (1955) Jan.

Description of production of a secondary alkyl sulfate detergent called Teepol

from petroleum stocks from wax cracking by the Shell Saint-Gobain Co. at their modern plant in Petit-Couronne, France. Carbon steel (ASTM Code A, 285 grade C) is generally used throughout the Teepol plant although special materials are used in the evaporation section and in part of the solvent recovery installation since the detergent solution is very corrosive at elevated temperatures. 18-8 stainless steel has been found satisfactory for the solvent recovery installation, and aluminum bronze and Monel are used in sections exposed to severe corrosion attack. An asphalt coating was applied over the carbon steel in the finishing tanks in order to prevent rust formation, and the finished product is stored in aluminum vessels. Materials of construction are tabulated. Illustrations, tables, 21 references.—INCO. 8857

8.9 Group 9**8.9.1, 6.5**

Possible Uses of Powder Metallurgy in the Aircraft Industry. (In French). N. THIEN-CHI. *Metaux*, 29, No. 347-348, 269-291 (1954) July-Aug.

A survey of the uses of powdered metals. Possibilities and limitations; hard metals (tungsten, molybdenum, tantalum, heavy metals and titanium); cermets (oxides, carbides or borides plus metal); porous bearings; friction materials; sintered electric contacts; magnetic materials; de-icing aircraft; semi-conductors.—BNF. 8814

8.9.2, 7.1, 7.4.1

Corrosion in the Motor Car. I. Corrosive Wear of Piston Rings and Cylinders. II. The Cooling System. Z. S. MICHALEWICZ. *Corrosion Technology*; 1; Nos. 6 & 9; 194-196, 199; 337-339 (1954) August, November.

I. Corrosion is a chief factor contributing to the wear of cylinders and piston rings of an automotive engine. It is caused by the acids formed in the combustion process. Mechanism of corrosive wear, together with the factors influencing it, is discussed, and some of the methods of mitigating the attack are reviewed.

II. Many forms of corrosion can be present in the cooling system, in which a hot coolant flows through a number of parts made of different metals, including cast iron, steel, Cu and brass, bronze, Al alloys and solder metal. Attack is aggravated by exhaust gas or air leakage into the system. Corrosion can be minimized by the use of effective inhibitors. Illustrations and 17 references.—INCO. 8626

8.9.3, 5.2.2

Alaskan Products Artery Nears Completion. B. E. BARNEs. *Oil Gas J.*, 53, No. 26, 99-100, 103 (1954) Nov. 1.

Line construction of 8-inch Alaskan products pipeline, running from Haines to Fairbanks, a total of 625 miles, has been completed. Entire line was laid bare but provisions were made to protect buried portions with magnesium anodes. Justification for not coating or painting stems from observations of the Canal pipeline system laid in World War II; lines laid bare on the ground suffered no damage from atmospheric corrosion.—INCO. 8486

8.9.3, 5.4.2

Cast-in-Place Steel-Cored Concrete Pipeline. R. M. SEDIJATMO. Paper before World Power Conf., Brazilian Sec. Mt. Rio de Janeiro, July 25-August 8, 1954.

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8.9.3, 5.4.5

Great Lakes. P. REED. *Chem. & Ind.* (1954) No.

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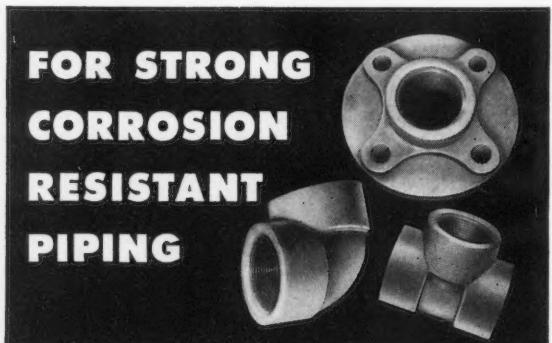
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Fluid Handling, No. 56, 247-250 (1954) Sept.

Cement covered stainless steel thin walled pipeline system suitable for water, oil or gas, which was successfully installed at the hydro-electric power station of Golang in Java, is described. It is claimed that it is suitable for high heads, possesses absolute water- and air-tightness, will withstand positive and negative pressure surges and may be cast in situ without expansion joints. It is suitable not only for hydro-electric plant penstocks but also for buried pressure lines for oil and gas. Pre-stressing of concrete pipes is covered.—INCO. 8645

8.9.3, 5.4.5, 5.4.10

Great Lakes Pipe Line Tests Coatings. P. REED. *Oil Gas J.*, 53, No. 27, 169, 171 (1954) Nov. 8.

Asphalt and coal-tar enamels are being used for coating pipe on different projects by Great Lakes Pipe Line Co. in order to evaluate materials and methods. Asphalt coating is applied on 163 miles of pipe, entirely by over-the-ditch methods and coal-tar enamel is used on 552 miles, applied by yard coating, railhead coating and over-the-ditch methods. Asphalt coating has been made impervious to petroleum and is reinforced with glass-fiber and coal-tar-impregnated, perforated asbestos felt wrappers.—INCO. 8721

8.9.3, 5.4.10

\$200 Million Down the Drain. *Bakelite Review*, 25, 16-18 (1954) January.

Illustrates application of pressure-sensitive vinyl tape to control corrosion on underground pipelines. Photographs.—BTR. 8502

8.9.5

Anti-Corrosive Paints for Ships. J. C. KINGCOME. *Corrosion Prevention and Control*, 1, Nos. 4 & 7, 207-214, 411-417 (1954) June, Sept.

Although cathodic protection is used extensively for ships in harbor, paint is the most widely accepted method for protection against corrosion in both merchant and naval vessels. Methods of surface preparation and pretreatment of steel and aluminum alloys are briefly dealt with. Description of the types of paints currently used for protection of the ship's hull and other exterior surfaces and also for interior surfaces is given. Twelve references.—INCO. 8551

8.9.5

Cities Service Supertankers Are Most Powerful Ever Built. *Marine Eng.*, 59, No. 11, 40-50 (1954) Nov.

Description of the structural features of 4 large tankers constructed for Grand Bassa Tankers, Inc., a subsidiary of Cities Service Co. To minimize the effect of acid corrosion in the cargo tanks, the *W. Alton Jones* and the *Statue of Liberty* are fitted with a dehumidifying plant which distributes dry air to the cargo tanks. Four-bladed propellers are of manganese-bronze. Elements in economizer of boiler are of Corten alloy with a porcelain coating to reduce corrosion. Drearating feed heater is rated to deliver 196,000 lb. of feed per hour at 277 F when supplied with 32 psig steam; feed temperature was increased to this figure over past design practice to minimize economizer corrosion. Illustrations, diagrams, list of equipment suppliers.—INCO. 8659

8.9.5, 1.3

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tained in one application. Where other factors are equal, the *thicker* the coating the *longer* the period of protection.

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DOREY, J. Inst. Metals, 82, Part II, 497-510 (1954) July.

A short historical survey on outstanding developments in the field of marine engineering is given, with special reference to some of the merits and limitations of non-ferrous metals. Combating corrosion still provides the most important function of these metals. Associated with this problem are those involving severe pitting caused by marine growth. Bio-fouling tends to be more severe on alloys having enhanced-corrosion-resistance. The use of dissimilar metals such as steel-to-aluminum presents contact-problems which are partially overcome by interposing galvanized strip or non-metallic packing and bolting with surface-protected steel bolts and by the application of zinc chromate paint or zinc coating. Aluminum alloys are claimed to have a high resistance to corrosion in contact with oil and petroleum products. One of the most severe problems is cavitation erosion. Erosion losses were found to increase with increase of sea water temperature. The use of light alloys in ship construction is increasing owing to the following advantages: 1) reduction in topside weight which increases the stability of the vessel, 2) increased corrosion-resistance of the aluminum alloys, 3) greater flexibility in the design, 4) ease of cleaning, 5) non-magnetic characteristics, 6) increased speed with the same machinery power. For structural purposes aluminum alloys with up to 5½% magnesium are most

suitable showing reduced tendency for precipitation of the β -phase and therefore reduced stress-corrosion. Aluminum-4% magnesium alloys are more suitable for hot working. They show good mechanical properties and good welding characteristics. The alloy with 5% magnesium is used for rivets. The high-strength, heat-treated Duralumin and aluminum-magnesium-zinc types of alloy are not employed in marine construction because of their inferior corrosion-resistance. The ultimate tensile strength of aluminum alloys used in ship construction is still relatively low, 20 tons/sq. in., being an almost limiting value for normal plates and sections. The article concludes with a survey on electrical features of non-ferrous metals and their application for electrical conductors, fusion jointing and deposition of metals and fabrication features.—ALL. 8510

The first successful applications of basic brick to the roofs of copper ore melting reverberatory furnaces consisted of hard-burned magnesite type located in the side charge-hold areas of sprung arches where erosion was most rapid. Silica brick were used in the center sections of these roofs. Combination basic-silica roof construction gave longer service than that of all silica. Illustrations, 2 references.—INCO. 8639

8.10.4, 3.5.9

Low Cost Materials, Methods Required by Rockets, Missiles. C. E. HAWK, Aerojet-General Corp. *Western Metals*, 12, No. 8, 45-48 (1954) August.

Study based on Aerojet-General's Aerobee-Hi sounding rocket is presented. Of the materials tested for the propellant tanks, 410, 414 and 431 chromium steels were selected as having the best all-around properties. Table lists "figure of merit" for the various materials including 410, 414 and 431, 4130, Haynes 25, Carpenter 20, Hastelloy C and 347; value is based on yield strength \div specific weight \times weld factor. Rocket parts exposed to elevated temperatures utilize conventional materials used on turbojet engines such as 347, Haynes 25, Inconel and Inconel X. Where corrosion resistance and moderate heat resistance are necessary objectives, precipitation-hardenable stainless steels (Armco's 17-7 PH and 17-4 PH) are used. Aluminum and titanium alloys are also discussed.—INCO. 8411

8.10 Group 10

8.10.2, 6.6.6

Current Refractory Practice as Applied in Copper Smelting. W. F. ROCHOW AND L. A. MCGILL, Harbison-Walker Refactories Co. *J. Metals*, 6, No. 3, 338-342 (1954) March.

Discussion of the principal furnace equipment, such as ore melting reverberatory furnace, converters and holding and smelter anode furnaces, of the modern copper smelter which requires careful selection of refractory lining materials.

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Either way, you're right

Maybe your company runs its own corrosion control program. Perhaps you regularly call in a reliable service organization for this important job. Either way, you're on the right road if you, or your service people, use top-quality DIAMOND corrosion control chemicals—sodium chromate and sodium bichromate. DIAMOND can deliver them quickly from strategi-

cally located, ready-to-ship stocks.

DIAMOND offers technical help and service on problems involving corrosion control. Call your DIAMOND Sales Office in Chicago, Cincinnati, Cleveland, Houston, Memphis, New York, Philadelphia, Pittsburgh or St. Louis. Or write to DIAMOND ALKALI COMPANY, 300 Union Commerce Building, Cleveland 14, Ohio.



**Diamond
Chemicals**

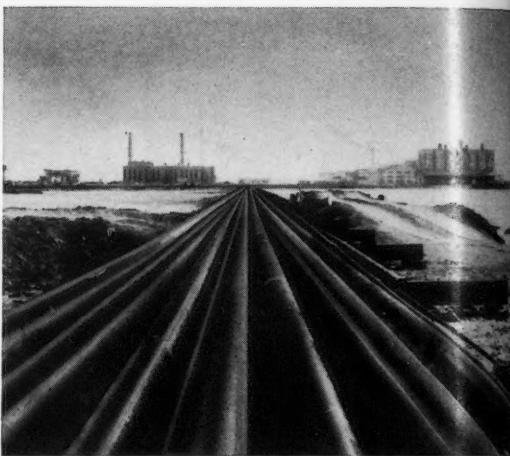
Here's how they
KO'd
 SULPHUR, CHEMICALS
 SALT AIR and HEAT
 on this Refinery Pipe line!



1. It takes no special equipment to apply Pitt Chem. Here, applicators brush on 101 about 12 mils thick.



2. Pitt Chem applies easily, even on awkward underside. Crew learned to apply it in a few minutes.



3. Pitt Chem 101 was economical to purchase and apply. It will protect this line against corrosion for years.

MAINTENANCE engineers at this Southwestern refinery realized that no ordinary coatings could protect these pipelines from the metal-eating conditions they faced. Today, the lines are safely protected with an impervious film of **Pitt Chem® Tar Base Coating**, the material that naturally resists practically all major types of industrial corrosion.

Pitt Chem Tar Base Coatings are tailor-made for protecting oil producing and refining equipment against corrosion. They are highly resistant to petroleum products as well as mineral acids, alkalis and moisture. They are economical to buy and easy to apply.

No other material does such a complete job of protection at so little cost. That's a big

statement, but our corrosion engineers have the facts to prove it.

If you have a corrosion problem—and never mind how tough it seems—contact us today. You may be surprised how quickly and economically it can be solved.



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